TABLE OF CONTENTS

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THE HAWAIIAN PLANTERS' RECORD

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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Notes in Reference to the Introduction and Distribution in Hawaii of Yellow Caledonia and Rose Bamboo Canes

By Walter M. Giffard
(*Honorary Member of Hawaiian Sugar Planters' Association*)

In 1876, the writer held a clerical position with the late firm of W. G. Irwin and Company, then a copartnership, consisting of John S. Walker, Z. S. Spalding and William G. Irwin.

At this period the lowland canes were mostly, if not altogether, the Lahaina, and the upland fields were planted with the so-called native varieties. In Kau, I believe that the latter predominated on the lower as well as the upper lands.

General interest in new varieties was not altogether lacking, but it was not until 1879 or 1880 that concerted effort was made to introduce foreign varieties for experimental purposes.

Because the origin of our cane varieties is of deep interest to all concerned in the Hawaiian sugar industry, it is important to record for future reference the recollections of those who were connected with the industry in its earlier years.

The following contribution deals with the introduction of the two varieties of sugar cane known as Yellow Caledonia and Rose Bamboo, about 1880, and the subsequent distribution of the first named variety to replace the then standard Lahaina. Lahaina, even at that time, nearly fifty years ago, was suspected to be gradually deteriorating in certain localities because of attacks of what was then known as Lahaina disease, now called root-rot.

W. G. Irwin and Company were agents, at that time, for two independent sugar plantations in Kau, the Hilea plantation and the Hutchinson plantation, both of which cropped only the so-called Hawaiian varieties. Charles N. Spencer, the manager of Hilea, an enthusiastic collector of native canes, developed a sudden yearning to add to his collection some foreign varieties, for experiment and comparison. To this end Spencer secured the personal cooperation of John S. Walker, then the senior partner of the firm of W. G. Irwin and Company, and prevailed upon Walker to procure for the Hilea collection a selection of some

of the best commercial varieties of cane grown in Queensland, Australia, in the hope that among these introductions there might be something that would eventually lead to a heavier production of sugar in Kau.

In due course, a selection of sticks of Queensland cane, comprising about twelve varieties, if I remember rightly, came consigned to W. G. Irwin and Company.

I have a distinct recollection of the receipt of this consignment and, in my clerical capacity, forwarding the package to Manager C. N. Spencer on one of T. R. Foster and Company's schooners at that time (1880-1881) freighting between Honolulu and the Kau ports.

Later, reports in Kau were to the effect that amongst the Queensland canes introduced, were two very promising varieties known at Hilea and Hutchinson plantations as Yellow Caledonia and Rose Bamboo. Word came to the Honolulu office that both these varieties were making an exceptional appearance alongside the native canes on Spencer's experimental plots.

Hilea plantation, in the meantime, had been incorporated as the Hilea Sugar Company, its stock owned entirely by W. G. Irwin and Company. After the death of Alexander Hutchinson, our firm bought his plantation and incorporated it. The Hutchinson mill was then at Naalehu. After Irwin and Company acquired the two places, they erected a newer and larger mill at Honuapo to grind the cane from both Hilea and Hutchinson, merging all of the sugar properties in the Hutchinson Sugar Plantation Company and discontinuing operation of the Hilea and Naalehu mills. While this was in progress, Honuapo had become the chief shipping port at the south end of the island.

The late John A. Scott, of Wainaku, Hilo, was the engineer in charge of the erection of the Honuapo mill. He continued as engineer until the owners transferred him to Hilo as manager of Wainaku plantation, which later became the Hilo Sugar Company, Limited.

While he was employed at Honuapo, Scott knew of Spencer's hobby of collecting and growing cane varieties. Later, when visiting there, he took note of the outstanding qualities of some of the new canes, especially the Yellow Caledonia. In many of his letters to W. G. Irwin and Company, written from Hilo, Scott, in discussing the need of better varieties, illustrated his theories by referring to the steady weakening of Lahaina cane at Waiakea's fields, near by.

He became much concerned over the possibility of the Lahaina disease spreading to the Wainaku fields from Waiakea and asked our office at Honolulu to get a few bags of Yellow Caledonia for him from Hilea, his idea being that if Lahaina should show signs of failure he would have another variety with which to replace it.

In consequence, a shipment of Yellow Caledonia seed cane was forwarded and in due course Scott planted quite an area with it. He in turn distributed cuttings to other plantations in the Hilo district. Later, seed of both Rose Bamboo and Yellow Caledonia were sent direct from Hilea to a number of other plantations, including Waimanalo, on Oahu. Waimanalo, I think, was the first plan-

tation on this island to get Rose Bamboo. I distinctly recollect the first shipment to us, after W. G. Irwin and Company became agents for this plantation.

This together with the following statements fixes the time of the introduction of these two canes from Queensland, Australia, as in the year 1880, by W. G. Irwin and Company, for C. N. Spencer at Hilea; and the first shipment of Yellow Caledonia to Wainaku about 1890; and the first commercializing of this variety by Hilo Sugar Company.

At this late date there is no documentary evidence to prove my contentions as to the way in which these two varieties of cane first reached Hawaii. However, I submit the testimony of three men who were cognizant of the facts, viz.: the personal recollections of Ned Robbins, who was a cane planter and head overseer at Hilea and Naalehu from 1877; of Harry V. Patten, formerly bookkeeper at Hilea; and of H. Jensen, a luna at Hutchinson plantation in 1885. Their testimony forms an interesting contribution to the history of the sugar industry in Kau, and is appended herewith:

1. Letter from Harry V. Patten to W. M. Giffard, dated Hilo, May 1, 1926.

The other day I met a man (H. Jensen) who worked for years at Naalehu, and in talking with him, he told me that he went to Hutchinson Plantation in 1885. . . He is about the last of the old crowd formerly there; was a mule luna for years, and his word can be given full credence.

Under date of May 20, 1926, in answer to further correspondence, Mr. Patten again wrote:

Mr. Jensen is thoroughly reliable and knows what he is talking about. At present he is a sick man and will probably not live long. Mr. Robbins is the only one left who could make a statement of any value.

I had already obtained the following testimony from Mr. Robbins, in 1923, when I interviewed him at his home. My notes, taken at the time of the interview, are as follows:

Mr. Robbins: I began planting cane at Hilea in 1877. The plantation was then called "Hilea plantation." It was incorporated later under the name "Hilea Sugar Company," and afterwards was merged into the Hutchinson Sugar Plantation Company.

I was head luna at Hilea plantation under the late Charles N. Spencer for some years, beginning in 1877, and later was employed as head overseer by the Hutchinson company. The Hilea mill foundations were begun in 1878. They were constructed by John Bowler. The mill was erected shortly afterwards.

C. N. Spencer, the manager, was formerly overseer and planter with Alexander Hutchinson at Waiohinu. He had been previously in the pulu business with George W. C. Jones, both Spencer and Jones having lost most of their pulu while it was stored for shipment at Punaluu, Kau landing, during the big tidal wave and volcanic outbreaks from the slopes of Mauna Loa.

Through J. S. Walker, of the firm of Irwin and Company, Spencer was appointed manager of Hilea plantation from its inception. Spencer was much interested in collecting Hawaiian canes as a hobby, and had quite a number of varieties planted at and near Hilea and at Waiohinu, while I was in the district. I know of his having written Walker for some cane varieties from Queensland, Australia.

During my stay in Kau I kept a plantation diary for some years and noted therein special work and events as they happened, but unfortunately during my recent illness this diary and other papers that were in a way important to me, were inadvertently burned by members of my family while cleaning up the house. As a result I am not positive as to dates, but have clear recollection of the matters you have reference to. I recollect when a box of several varieties of what I was told was Queensland cane came consigned to Spencer. It was about 1877 or perhaps 1878—I am not sure—it may have been a year or two later. I also recollect Spencer sending a consignment of 15 or 20 varieties of Hawaiian canes to Wm. G. Irwin and Company, for exhibition at an agricultural show held at Honolulu in 1878, and that these received a prize.

My remembrance is that the Queensland canes came in large sticks and that our so-called Yellow Caledonia and Rose Bamboo were among the varieties received. Some years later I also remember putting up samples of the Yellow Caledonia variety which were intended for Wainaku plantation in Hilo. Later, further lots were sent to Wainaku and other plantations. I think some was sent also to Hakalau at the request of W. G. Irwin and Company.

The following is a copy of a letter dated Olaa, May 19, 1926, by H. Jensen to Harry V. Patten, which the latter loaned me. Patten was bookkeeper at Hilea Plantation during a part of the period referred to:

H. Jensen, witnessed by Mrs. Puuheana Jensen: With reference to my conversation with you I desire to make the following statements regarding the introduction of Yellow Caledonia and Rose Bamboo into the Hawaiian Islands:

In 1885, I was employed as a luna on the Hutchinson plantation at Naalehu, Kau, Hawaii, and remained in its employ some years. My work often took me to the neighboring section at Hilea, then managed by the late Charles N. Spencer. Mr. Spencer had a fad for collecting many varieties of sugar cane. I remember that on the adjoining land of Wailau he had at least 16 varieties, from which some, later on, were selected for distribution in the district, while others already had been planted elsewhere on his land.

Amongst the promising canes I remember most particularly the three varieties, Yellow Caledonia, Rose Bamboo and Whitney Bamboo. Mr. Spencer claimed that about five years previous, about 1880, he had received a collection of Queensland canes from his Honolulu agents, W. G. Irwin and Company, which they, at his request, had sent to Queensland for, to add to his collection, and that among these there were what we called Yellow Caledonia and Rose Bamboo varieties.

Mr. Spencer also claimed at that time that he grew the so-called "Whitney Bamboo" from the tassel seed, but whether his statement as to this was correct or not, I am not sure.

I am sure, however, that Yellow Caledonia and Rose Bamboo canes were growing in small areas in 1885 on the land of Wailau, at Hilea plantation, Kau; that these canes had been growing there for some time previous; and that some years after 1885 the first consignment of Yellow Caledonia seed was sent to Wainaku, Hilo, from Hilea, by Mr. Spencer, at the request of Wm. G. Irwin and Company, who were also agents for Wainaku plantation, now Hilo Sugar Company.

There is one more brief note to append. The late John A. Scott always claimed that he got his first seed from Hilea in 1890, which corroborates my own recollections. The following, from the files of the Hilo Tribune of April 10, 1897, under the caption, "Earlier Days in Hilo," undoubtedly had reference to some later sample shipments which were sent to W. G. Irwin and Company, for distribution elsewhere than to Wainaku:

William G. Irwin, of Honolulu, is in receipt of several excellent samples of Yellow Caledonia cane grown on Hutchinson plantation in the Kau district on the island of Hawaii.

The Eye Spot Infection Index and Tolerance Index of Seedlings Tested to Date

The Hawaiian Planters' Record for October, 1926, contained an article entitled, "A Method of Testing Cane Varieties for Eye Spot Susceptibility and Resistance," by H. Atherton Lee, J. P. Martin and C. C. Barnum. In this article the methods used in determining the eye spot infection index as well as the eye spot tolerance index of new seedlings were described. With these tests the eye spot resistance or susceptibility of any seedling may be determined in ten days time with very accurate results. Such tests are extremely useful in establishing the eye spot index of newly introduced canes.

Since the publication of this article in the *Record*, many more seedlings other than those reported in the above article have been subjected to similar tests. The object of this report is to present a complete list of all seedlings tested to date, including those seedlings previously reported on as well as those tested since October, 1926.

The methods employed in these tests may be briefly described as follows: All determinations are based on inoculation tests of eye spot susceptibility of cut stalks of the various varieties. These cut stalks are placed in a sulphurous acid solution (1 part of sulphurous acid in 3300 parts of water, as developed by J. A. Verret and his associates). Ten stalks of each variety as well as ten stalks of H 109 controls were used in each test. Usually 5 to 7 varieties were tested at the same time in a large moisture cage. Eye spot spores from pure cultures of the fungus *Helminthosporium sacchari* Butl. were sprayed on all foliage uniformally. At the end of 10 days the total number of eye spot infections as well as the total length of all lesions and the resulting runners were determined. From these figures the accompanying tables were derived.

In Table I, the eye spot infection index of each seedling tested is given. The various seedlings are placed in order of their resistance as compared to H 109, with the most resistant listed first.

In Table II, the eye spot tolerance index of each seedling is given. Here again the seedlings are placed in order of their tolerance as compared to H 109, with the most tolerant seedling listed first. More than one test was made on a great number of seedlings and the number of tests conducted on each seedling is noted in Table II. In such cases where more than one test was made the eye spot infection index and tolerance index presented in Tables I and II are the averages of the results on each seedling.

The arrangement of the seedlings in Table II has more commercial value when selecting a seedling that is to be planted in an eye spot locality. The number of individual infections on one variety may be the same as or even greater than on another variety, but if long streaks or runners are produced on one and not on the other, then the variety without the runners has far greater resistance than the other. Any seedling with a tolerance index of 500 or less may be regarded as commercially resistant to the eye spot disease. A seedling with a tolerance index

TABLE I

EYE SPOT INFECTION INDEX

1–100	Infection Index No.	100–250	Infection Index No.	250–500	Infection Index No.	500–750	Infection Index No.	750–1000	Infection Index No.	1000	1000 +	Infection Index No.
P.O.J. 213	2	Waipahu 36	161	Waipahu 30	251	Waipahu 31	509	H 9923	768	H 109	McBryde 1	1001
P.O.J. 234	3	Yel. Cal.	174	H 8994	261	H 8942	511	H 8988	775		25–C–22	1005
Uba	34	20–S–16	174	Kassoer	266	U.D. 1	531	25–C–9	785		25–C–17	1015
Badila	36	P.O.J. 2727	180	H 8993	275	Wailuku 11	532	25–C–8	800		25–C–10	1061
P.O.J. 979	73	P.O.J. 36	181	Yel. Tip	287	D.I. 52	539	Paia F	860		McBryde 5	1099
		Makaweli 3	183	H 8965	289	H 86484	540	McBryde 3	869		25–C–13	1129
		Waipahu 51	185	H 8961	343	Paia 186	549	25–C–6	879		H 8906	1132
		Waipahu 89	214	Waipahu 81	357	H 81360	608	25–C–12	885		H 86441	1216
		25–C–15	247	H 8952	360	25–C–14	682	Paia 180	901		25–C–5	1441
				P.O.J. 2714	387	Makaweli 476	682	B.H. 10/12	913		Wailuku 8	1575
				25–C–1	405	25–C–11	686	H 89102	915		25–C–19	1756
				25–C–3	419	25–C–16	717	Wailuku 3	921		Ewa 628	1935
				S.W. 3	429	25–C–4	745	Wailuku 2	923		Ewa 800	1938
				Waipahu 35	451			25–C–21	929		Ewa 371	2356
				P.O.J. 2725	493			Paia D	931		Ewa 580	3034
								25–C–20	959		Ewa 57	3097
								Paia 75	960		25–C–18	3599
								McBryde 4	968			
								Onomea H 109 self	985			
								25–C–7	991			
								Paia 150	997			

TABLE II

EYE SPOT TOLERANCE INDEX

0.1–100	Tolerance Index No.	No. Tests Made	100–250	Tolerance Index No.	No. Tests Made	250–500	Tolerance Index No.	No. Tests Made	500–750	Tolerance Index No.	No. Tests Made	750–1000	Tolerance Index No.	No. Tests Made	1000	1000 +	Tolerance Index No.	No. Tests Made
P.O.J. 213	.10	3	H 81360	132	2	25–C–11	253	1	25–C–20	504	1	McBryde 4	816	3	H 109	Makaweli 476	1089	1
P.O.J. 234	1	3	25–C–6	149	1	25–C–21	273	1	Wailuku 11	523	3	Onomea H 109 self	826	1		Ewa 800	1104	1
Badila	7	2	25–C–3	156	1	P.O.J. 2727	300	3	25–C–13	567	1	H 96441	837	3		25–C–19	1125	1
Waipahu 51	12	1	25–C–1	180	1	25–C–12	325	1	H 89102	574	1	25–C–17	879	1		McBryde 1	1149	2
Uba	14	2	P.O.J. 2714	186	3	H 8965	342	2	B.H. 10/12	588	3	Wailuku 29	890	3		Paia D	1177	2
Waipahu 30	15	1	25–C–16	188	1	D.I. 52	351	3	25–C–7	670	1	Wailuku 2	896	3		Wailuku 8	1203	3
Waipahu 36	18	1	Kassoer	188	3	P.O.J. 2725	366	3	25–C–9	670	1	H 8906	921	1		Ewa 628	1250	1
P.O.J. 979	40	3	Waipahu 31	192	1	H 8942	381	2	McBryde 3	674	3					Paia F	1260	2
Makaweli 3	45	3	P.O.J. 36	211	3	Paia 186	384	2	H 9923	696	3					25–C–5	1269	1
H 8993	47	1	25–C–14	225	1	H 86484	404	3	25–C–10	706	1					Ewa 580	1345	1
Waipahu 35	48	1	S.W. 3	243	3	25–C–4	409	1	Paia 180	709	2					Paia 150	1455	2
H 8961	57	1				25–C–22	431	1	25–C–8	726	1					25–C–18	1890	1
Yel. Cal.	59	1				H 8988	444	1								Ewa 57	1922	1
Yel. Tip.	62	2				U.D. 1	453	3								Ewa 371	1938	1
Waipahu 89	69	1														McBryde 5	2397	1
25–C–15	70	1														Paia 75	2720	2
Waipahu 81	71	1																
20–S–16	72	2																
H 8994	77	3																
H 8952	82	1																

between 500 and 1000 should never be planted in bad eye spot areas, but may be planted where eye spot is never considered a serious problem. No eye spot areas should be planted with seedlings with a tolerance index of 1000 or more.

The majority of canes tested show a higher degree of resistance to eye spot than H 109. Some of the seedlings, such as P. O. J. 213, 234, 979, 36, Badila, Uba, Yellow Caledonia and Kassoer, possess outstanding resistance to the disease.

J. P. M.

P. O. J. 36

P. O. J. 36 alongside D 1135 at Mountain View, Olaa; the larger cane at the right is the Java seedling propagated in 1897, and imported into Hawaii in 1923 as one of the first group of canes that gained entrance to the Territory when the custom of prohibiting cane introductions was modified to permit the entrance of certain varieties that had undergone quarantine at Washington, D. C.

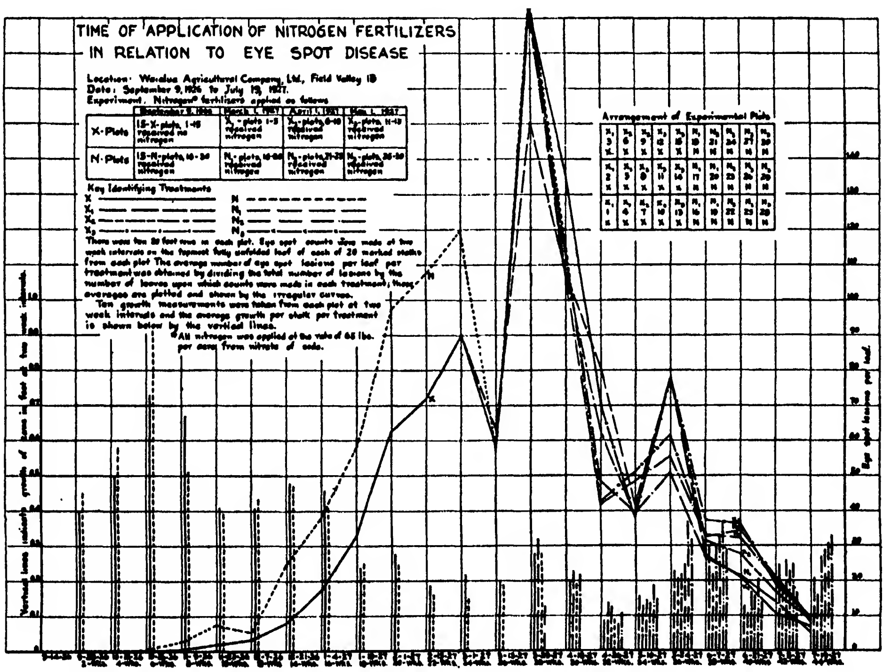
The Time of Application of Nitrogen Fertilizers in Relation to Eye Spot Disease

By J. P. Martin and H. Atherton Lee

Our present data from experimental results have repeatedly shown that late fall applications of nitrogen fertilizers to those fields subject to eye spot, increased the disease very materially. To prevent this increase of the disease, applications of nitrogen fertilizers should be avoided, if possible, in the fall months, or the amount of nitrogen applied at that time should be greatly reduced.

To determine the optimum time in the early spring months to apply nitrogen without materially increasing the disease, the following experiment was planned and conducted during the eye spot season of 1926-1927, in Field Valley 1B, of the Waialua Agricultural Company, Ltd. This experiment extended over a period of forty-four weeks or from September 9, 1926, to July 19, 1927.

Field Valley 1B was planted to H 109 cane July, 1926, and an area of sufficient size for the experiment was selected previous to the time of any application of fertilizers by the plantation. In the early part of September, 1926, 30 plots of 10 rows of cane each were laid out in the selected area. Each row was 30 feet in length, and each plot was 1/28th of an acre in area. The arrangement is shown in the upper part of the accompanying illustration.



The number of eye spot infections was counted at two-week intervals on the topmost, fully unfolded leaf of each of twenty marked stalks in each plot. The average number of eye spot lesions per leaf per treatment was then obtained by dividing the total number of lesions by the number of leaves upon which counts

were made in each treatment; these averages were then plotted as shown in the illustration.

At two-week intervals growth measurements were made on each of ten stalks in each plot. The average growth per stalk per treatment was computed from these measurements and plotted at two-week intervals as shown by the vertical lines on the graph. Each vertical line represents a different treatment.

The applications of nitrogen to the experimental areas were made at various times and may be best presented in the table. All nitrogen was applied at the rate of 65 pounds per acre in the form of nitrate of soda.

SHOWING TIME OF APPLICATIONS OF NITROGEN TO THE VARIOUS SERIES OF PLOTS IN EXPERIMENT 1

X-PLOTS	September, 1926 15-X-plots, 1-15 received no nitrogen	March 1, 1927 X-plots, 1-5 received nitrogen, 65 lbs. p. a.	April 1, 1927 X_2-plots, 6-10 received nitrogen, 65 lbs. p. a.	May 1, 1927 X_3-plots, 11-15 received nitrogen, 65 lbs. p. a.
N-PLOTS	15-N-plots, 16-30 received nitrogen, 65 lbs. p. a.	N-plots, 16-20 received nitrogen, 65 lbs. p. a.	N_2-plots, 21-25 received nitrogen, 65 lbs. p. a.	N_3-plots, 26-30 received nitrogen, 65 lbs. p. a.

It is interesting to note the amount of cane growth as recorded between the dates of October 12 to October 26, 1926; the plots which had received nitrogen averaged a longitudinal growth of 10.92 inches per stalk as compared to 8.76 inches per stalk for plots receiving no nitrogen. However, the plots receiving nitrogen, with a few exceptions, did not register as much growth in subsequent weeks as the control plots. The cane in both treatments of this experiment made very good growth during the winter months, especially up to January 4, 1927, and after that date the growth of the cane was quite uniform to March 29, 1927. The smallest amount of growth was recorded during the latter part of April which was the month when the most rainfall occurred during the experiment. The extra amount of nitrogen fertilizer in this experiment did not give a marked increase in growth during the winter months.

Eye spot often occurs in fields where the soil is very fertile and where weather conditions favor the disease. As may be observed in the illustration, eye spot started to increase during November and the first part of December, while after December 7, 1926, the disease increased much more rapidly, and a peak was reached on March 1, 1927. A second peak was established on March 29, 1927, while still a third peak was recorded on May 24, 1927. After May 24, 1927, the disease decreased very quickly, as shown by the curves. On March 1, 1927, or at the first eye spot peak, the plots receiving nitrogen had 43.18 per cent more eye spot than the plots receiving no nitrogen.

The vertical growth columns and eye spot curves show that there was a decrease in growth correlated with an increase in the degree of eye spot infection. This correlation has been evident in all eye spot experiments where growth measurements and eye spot counts have been recorded. Apparently weather con-

ditions that are most unfavorable for cane growth are most favorable for the increase of eye spot disease.

The applications of nitrogen that were made on March 1, April 1, and May 1, 1927, had little effect on the amount of eye spot that occurred in the various treated plots, as may be readily observed by referring to the illustration; all curves representing the various treatments show a very small difference after March 15, 1927, to the end of the experiment. Since this field was so fertile, as shown in the illustration by comparing the growth of the no-nitrogen-treated plots versus those plots receiving nitrogen after the first six weeks of the experiment, the extra amounts of nitrogen fertilizer applied in the early spring months had little or no effect on the severity of the disease. The eye spot disease rapidly decreased after March 29, 1927, at nearly the same rate that it increased from November 9, 1926, to March 29, 1927.

Summary

1. In the field in which this experiment was conducted, plots receiving an extra application of nitrogen in the fall months did not give a marked response in cane growth as compared to cane receiving no nitrogen.
2. The added amount of nitrogen fertilizer in the fall months increased eye spot infection.
3. The decrease of cane growth during the winter months was coincident with an increase of eye spot infections.
4. All late planting of cane in eye spot areas should be avoided during the fall months, and this in turn automatically eliminates the necessity of any late application of nitrogen fertilizers.
5. Applications of nitrogen fertilizers in March, April and May, did not result in seriously increasing eye spot infections in this experiment.

The Possible Influence of Zinc and Phosphates in Giving Resistance to Eye Spot in H 109 Cane

By F. E. Hance and G. R. Stewart

In February, 1927, George Chalmers, Jr., manager of Waimanalo Sugar Company, requested that we try to find whether there were definite differences in the composition of the soils or of the cane growing in eye spot susceptible fields, contrasted to the soil and cane composition in areas where eye spot did not occur. At Waimanalo, eye spot has invariably appeared in certain portions of the upper fields where the land has been in cultivation for about fifty years. On the lowland areas where cane has been grown for a shorter period, eye spot infection has never been a problem.

Recent investigations by Brenchley (1), McHargue (5), Sommer (6), and others, have shown that minute amounts of a number of the rarer elements are essential for many common plants. We have no definite information as to the

nutritional requirements of sugar cane for any of these less essential materials. It is, however, quite probable that the sugar cane plant has an actual need for some of the less usual plant nutrients.

It therefore appeared to us to be desirable to investigate the composition of the H 109 cane at Waimanalo, both in regard to the usual plant food constituents and the rarer mineral elements. We have obtained some evidence in pot studies that traces of arsenic and copper have apparently acted as stimulants in promoting increased growth.

Experimental Data

Samples of cane plants and soil were collected from the following representative areas:

No. 1—Field 18. Bad eye spot area.
No. 2—Field 18. Area of slight eye spot infection.
No. 3—Field 17. Badly infected area.
No. 4—Field 17. Area of slight eye spot infection.
No. 5—Field 11. Severe eye spot infection.
No. 6—Field 2. Good cane—no eye spot.

Determinations of the available, reserve and total nutrients were made on the above soil samples. The cane was examined for iron and aluminum injury and a spectroscopic examination of the cane ash was made for the detection of the rarer elements. The analytical data appear in the following table:

DATA OF WAIMANALO EYE SPOT INVESTIGATIONS

			Examination of Soils							Examination of Cane Plants	
Field	Condition of cane	pH	Total P_2O_5	HCl Reserve P_2O_5	Citric Avail. P_2O_5	Total K_2O	Available K_2O	Maximum H_2O holding capacity	Hygro. Coef.	Fe and Al Injury	Spectroscopic analyses
18	poor	6.25	.188	.087	.0017	.304	.039	89.5	22.5	None	No zinc
18	good	7.84	.295	.147	.0028	.446	.057	79.3	20.8	"	Zinz present
17	poor	5.81	.305	.170	.0015	.281	.069	75.8	21.2	"	No zinc
17	good	7.22	.303	.138	.0021	.320	.080	78.1	21.7	"	Zinc present
11	poor	6.88	.290	.158	.0012	.368	.059	84.4	22.8	"	No zinc
2	good	7.54	.380	.217	.0664	.502	.111	72.1	19.6	"	Zinz present

For the spectroscopic analyses the stalks and leaves of the cane were ashed separately at a low temperature. The residue was taken to dryness several times with hydrofluoric acid and the material remaining was dissolved in dilute (6 normal) hydrochloric acid. The spectroscope revealed very small traces of zinc in the leaves of the cane which offered the greatest resistance to eye spot disease The cane which suffered from the greatest infection gave no evidence whatsoever of the presence of zinc. The cane from the lowland area gave the most positive test for traces of zinc. By itself this spectroscopic data would be of little value without a long series of equally positive determinations, but we have additional evidence of the influence of zinc in other eye spot studies. In a cooperative investigation carried on with H. Atherton Lee, of the department of pathology, at this Station, we undertook to grow H 109 cane in the presence of traces of various

uncommon inorganic compounds. Among the materials employed, zinc oxide (5 grams in 30 kilos soil) constituted one series of six repetitions.

When the plants in the entire experiment reached the age of four months they were placed in a humidity house and were sprayed with an infusion of eye spot spores. This work was handled by the pathology department under Mr. Lee's direction. After ten days' exposure to the spores in the humid atmosphere the plants were removed and Mr. Lee's staff made a quantitative count of the lesions resulting from the development of the disease.

In the series of treatments it appeared somewhat significant that the cane which had been grown in a zinc environment appeared fourth on the list of eleven so arranged as to show decreasingly progressive resistance to the disease.

In connection with the value of zinc in plant economy, Brenchley (1), of the Rothamsted Experimental Station, states: ". . . zinc is regarded as a catalytic element, as essential to the well-being of the plant as are the more obvious nutrients, carbon, sulphur, phosphorus, etc., in spite of the minute traces in which it occurs."

Traces of zinc are regarded as essential by Maze (4) and Javillier (3).

Ehrenberg (2) concludes that zinc leads to increased growth in plants by an indirect action in the soil.

In order to obtain additional information on the effect of zinc, Mr. Chalmers has reserved a portion of one of his fields in which eye spot appears every year. T. K. Beveridge, agriculturist at Waimanalo, has laid out a series of plots and check plots in the reserved area. He has made one application of zinc oxide in the plots to the surface soil along the rows of a second ratoon H 109 cane. Additional applications will be made so that a total of about twenty pounds of zinc oxide per acre will be applied.

Any effect from the zinc will be observed during the next two seasons at the height of development of the eye spot disease. Royden Bryan, of this Station, has kindly agreed to make quantitative lesion counts on both the check and zinc-treated plots.

The analyses of the soil from the good and poor areas indicate that where the available nutrients are in higher concentration, the cane passed through the season with less infection. This is particularly true in regard to phosphoric acid. The soil, even in the mauka areas, which supported resistant cane, was invariably richer in available P_2O_5 than that near by on which the cane was badly infected. In the sample from the lowland area where eye spot never appears, the available P_2O_5 was quite high.

Increased phosphate applications have been made to the eye spot areas at Waimanalo. The effect of this treatment on the resistance of the cane is being followed with interest.

Summary

The foregoing observations are only offered as a tentative progress report. The spectroscopic determinations which show the presence of minute traces of zinc in the eye spot resistant cane, combined with the results of the pot tests, which showed increased eye spot resistance, in the cultures where small zinc

applications were made to the soil, would suggest that the presence of minute amounts of zinc may make the cane plant less susceptible to the fungus.

The soils of the areas which are free from eye spot on this one plantation appear to be better supplied with available phosphates than the soils of the eye spot fields. There is therefore a second possibility that a better balance of plant nutrients and particularly of phosphates may aid in giving the cane eye spot resistance.

The field trials which are at present under way at Waimanalo should throw some light on the relative influence of these two factors which our experiments show may affect the cane in the good and poor areas. We shall not attempt to draw any definite conclusions on the basis of our present work until it is supplemented by further data on treated and untreated plots in the field.

Literature Cited

(1) Brenchley, W. E. Inorganic plant poisons and stimulants. Cambridge University Monograph, p. 36 (1914).

(2) Ehrenberg, P. Wirkungen des Zinks bei Vegetationsversuchen. Landw. Versuchs—Stat., *73*, 15-142 (1910).

(3) Javillier, M. Seventh Int. Congress Appl. Chem., Section 7, Ag. Chem., 163 (1910).

(4) Maze, P. Recherches d'une solution purement minerale capable d'assurer l'evolution complete du mais cultivee a l'abri des microbes. Ann. Inst. Pasteur *33*, 139 (1919).

(5) McHargue, J. S. The role of manganese in plants. Jour. Amer. Chem. Soc. 44; 1592-1598, 1922.

(6) Sommer, A. L. and Lipman, C. B. Evidence on the indispensable nature of zinc and boron for higher green plants. Plant Physiology, Vol. I, No. 3, pp. 231-249.

The Effect of Covering on the Germination of Sugar Cane Fuzz

By C. G. Lennox

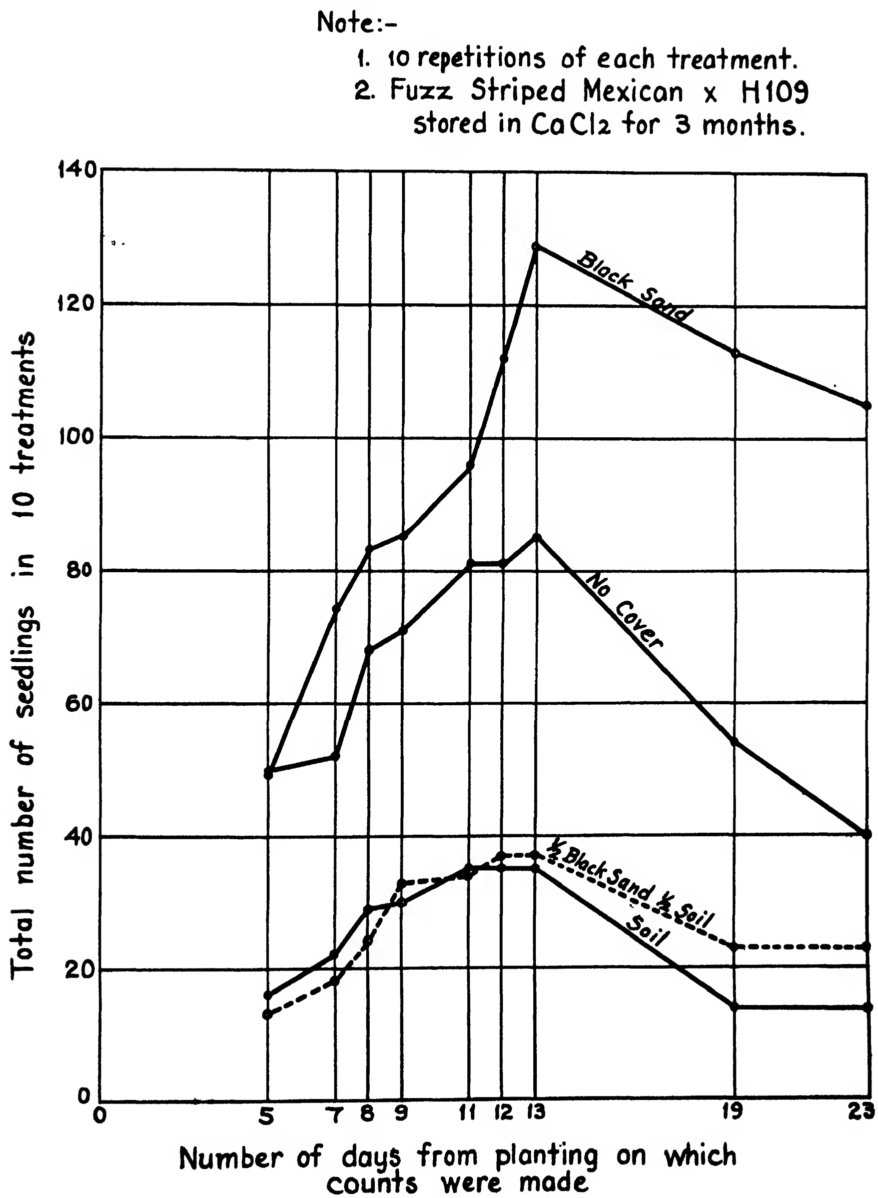
During the 1926-1927 seedling season a number of studies were made in an attempt to further improve the technique of seedling germination. The use of bottom heat was found very advantageous in promoting quicker and greater germination. Sunlight is shown by Das (1) to be conducive to germination and as much as possible should be given. The use of uspulun on the fuzz flat is still questionable, but it was found very effective by Das (2) in preventing damping off in seedlings newly transplanted from the germinating plot. Sprinkling the young seedlings with a weak solution of ammonium sulfate stimulated growth. The use of a weak, full nutrient solution was reported by Davis (3) as very beneficial in aiding germination and growth. The practice of keeping the fuzz flats covered with thin oil paper until germinations appeared was followed. In efforts to find some other suitable covering medium, sifted volcanic ash was tried with good results.

In the first investigations on covering mediums, Striped Mexican fuzz was used. This fuzz had been stored for three months over calcium chloride. Twenty

flats of the same size were planted to this fuzz. Each flat was then divided in half, each half receiving a different treatment. Ten halves received no covering, ten received a covering of black sand (volcanic ash) sifted through a "tenth-inch mesh" wire screen, ten received a finely sifted soil covering, and ten received a covering of the mixture of half black sand and half soil. The flats were then placed on an outside hot table and given uniform conditions.

The accompanying illustration shows the relative values of the treatments. The coverings of soil and of mixtures of soil and black sand were very deleterious

Germinations with Coverings on the Seed Bed



to germination. The following table, showing the percentage gain by use of black sand against no covering, is interesting:

	% gain of black sand covering over no cover at peak of germination	% gain of black sand covering over no cover at "pricking out" time
Black sand (volcanic ash)	52	160

These figures show that black sand has prevented a large percentage of those germinated from dying off. The mortality rate in black sand was only 18.6 per cent, while with no covering it was 53 per cent.

The results of these figures seemed so positive that further trials were made with the use of black sand and no covering. In these, fuzz from three different varieties was used. Ten flats of each fuzz variety were planted and one-half of each flat was covered with black sand, the other left uncovered. The positive results are again illustrated in the following table:

Variety of fuzz	Total area in sq. ft.		No. germinations fourteenth day		No. per unit area fourteenth day		% Gain by use of cover
	Cover	No cover	Cover	No cover	Cover	No cover	
H 146 x Badila	6.6	6.94	487.0	439.0	73.8	63.4	14 2
H 109 x H 456	6.61	6.99	42.0	30.0	6.35	4.3	48.0
20 S 16 self	6.81	6.78	83.0	59.0	12.2	8.7	40.0

As in the first experiment the mortality rate was greatly diminished by the use of black sand. The following table will illustrate this:

Variety of fuzz	No. per unit area at peak		No. per unit area at last count		% mortality	
	Cover	No cover	Cover	No cover	Cover	No cover
H 146 x Badila	73.8	67.0	69.7	55.4	5.5	17.3
H 109 x H 456	6.35	4.3	5.0	3.0	21.2	30.2
20 S 16 self	16.5	13.7	7.5	5.2	54.5	62.0

A third series of experiments was run in which white coral sand was used. The results as shown in the following table are not sufficiently consistent to warrant its substitution for black volcanic ash:

Variety of fuzz	Black sand vs. No cover			White coral sand vs. No cover		
	Cover	No cover	% Gain	Cover	No cover	% Gain
H 109 x 20 S 16	41	31	32	27	25	8
H 146 x Badila	165	94	75	111	130	14—loss
H 109 x H 27	12	8	50	15	13	15

In the above experiment white coral sand covering seemed to foster the growth of green algae regardless of uspulun treatments.

The beneficial functions performed by a covering of black sand seem to be twofold. First, the covering is of a sufficiently fine texture to keep a continuous film of moisture about the seeds and yet is sufficiently coarse to allow perfect aeration about the germinating seed. It also carries the moisture film high enough above the fuzz bed to feed those seedlings germinating on the top of the bed. Secondly, the black sand seems to prevent the growth of green algae. No trouble

with damping off was experienced in the use of the black sand. Furthermore the newly germinated seedlings may be more easily seen when a black sand covering is used.

SUMMARY

A covering of black sand (volcanic ash) sifted through a tenth-inch mesh wire screen and sprinkled over the fuzz bed in sufficient quantity to just cover the fuzz proved a satisfactory covering material. Covering the fuzz flats in this manner increases the percentage of germination, reduces the rate of mortality in the seedlings, keeps down the growth of green algae and forms a background against which the young green seedlings can be easily seen.

LITERATURE CITED

(1) Das, U. K. Effect of sunlight on germination of sugar cane seeds—P. F. 488.1, Oct. 31, 1925; Jan. 8, 1926; Exp. Sta., H. S. P. A.

(2) Das, U. K. Value of uspulum treatments on germination flats—P. F. 488.1, Feb. 27, 1926.

(3) Davis, R. L. Sugar cane seedling optimum culture. *The Planter and Sugar Manufacturer*, Vol. LXXVI, p. 328, 1926.

Additional Inoculation Tests With Sugar Cane Stem Galls

By H. ATHERTON LEE

The following is a report of further experiments to determine whether stem galls of the Uba hybrids are transmissible by direct inoculation.

The inoculations were made on the variety U. D. 1 at the Manoa substation; the cane had been fertilized with nitrate of soda about a month previously to put it in good, actively growing condition.

The inoculum for the controls consisted of fresh, young, actively growing cane tissues taken from the young top soft joints of normal U. D. 1 cane, and macerated with water in a mortar.

The inoculum for the inoculations consisted of newly formed, fresh, soft, actively growing stem galls from the tops of the U. D. 1 cane at the Mid-Pacific Institute substation. Such young galls in the first series of inoculations (21 to 40) were macerated with water in a mortar. In the second series (41 to 62) the young galls were macerated under a bland oil, Nujol, for the purpose of excluding oxygen which might injure a possible causal agent in the gall tissues.

Inoculations were made by splitting longitudinally through the leaf sheaths, with a knife or thumb nails, and exposing the youngest joints of the cane top; the inoculum was then placed in the tissues of such soft joints, by means of needle punctures. The actively growing meristematic tissue just above the node was selected as the point for the inoculation in this series of inoculations. The leaf sheaths were then drawn together over the point of inoculation, moist cotton placed over the split leaf sheaths, to add to the natural atmospheric moisture and

promote tissue growth, and the top of the cane stalk then wrapped in paraffin paper, and then in opaque paper to exclude sunlight.

These inoculations were made on June 6, 1927, and allowed to continue 86 days before examination, on August 31, an ample period for galls to develop. The inoculation data and results are tabulated as follows:

Stalk No.	Inoculum	Method	Result
1	Healthy tissue	Crushed	Neg.
2	do	in	Neg.
3	do	Water	Neg.
4	do	do	Neg.
5	do	do	Neg.
6	do	do	Neg.
7	do	do	Neg.
8	do	do	Neg.
9	do	do	Neg.
10	do	do	Neg.
11	do	do	Neg.
12	do	do	Rind slightly ridged near puncture
13	do	do	Neg.
14	do	do	Neg.
15	do	do	Neg.
16	do	do	Neg.
17	do	do	Neg.
18	do	do	Lost
19	do	do	Neg.
20	do	do	Neg.
21	Stem Galls	Macerated	Neg.
22	do	with water in	Lost.
23	do	mortar	Lost
24	do	do	Neg.
25	do	do	Neg.
26	do	do	Neg.
27	do	do	Neg.
28	do	do	Neg.
29	do	do	Neg.
30	do	do	Neg.
31	do	do	Lost
32	do	do	Neg.
33	do	do	Neg.
34	do	do	Neg.
35	do	do	Neg.
36	do	do	Neg.
37	do	do	Lost
38	do	do	Neg.
39	do	do	Neg.
40	do	do	Lost
41	Stem Galls	Crushed	Neg.
42	do	under bland	Neg.
43	do	oil (Nujol)	Lost
44	do	in mortar	Neg.
45	do	do	Neg.
46	do	do	Neg.
47	do	do	Neg.

48	do	do	Neg.
49	do	do	Neg.
50	do	do	Lost
51	do	do	Neg.
52	do	do	Neg.
53	do	do	Neg.
54	do	do	Neg.
55	do	do	Neg.
56	do	do	Neg.
57	do	do	Neg.
58	do	do	Neg.
59	do	do	Neg.
60	do	do	Neg.
61	do	do	Lost
62	do	do	Neg.

Seven inoculated stalks were observed with negative results, but labels were weathered or lost.

Conclusions

It would seem from the results of the foregoing inoculations, together with the results of previous inoculations that the conclusion is safe, that stem galls are not readily transmissible by direct contact.

It is still possible, but not probable, that stem galls are infectious, but depend upon insect vectors for transmission.

From the results of the inoculations with organic solutions such as ammonia, ethyl alcohol, etc., the most promising lead now seems to be a study of insects as direct inciting agents of these stem galls, through the injection of such chemicals into the soft actively growing cane tissues.

The Topping of Cane at Harvest

By J. D. Bond

At what point should cane be topped at harvest? Should it be at the growing point, or should the very soft stalk at the top be discarded, and if so, how much? Some have claimed that the discarding of the soft stalk at the top has not only shown better juices at the crusher, but an increased yield in sugar per acre. Others have claimed a loss for this procedure.

To answer this question under local conditions, the Ewa Plantation Company instituted a series of five tests during the crop of 1927 as below:

Test	Field	Date
1	2 A	January 21, 1927
2	23 C	February 10
3	23 B	June 3
4	23 B	June 7
5	A	July 29

In order to place these tests on a practical basis, it was decided to define the lower limit in topping as the removal of one seed piece of three eyes, with the top. This procedure was designated as "topping low." The upper limit was defined as the removal of the top slightly below the growing point so as not to remove any stalk, and so that the cross-section would show fibrovascular matter and no leaf spindle. This was defined as "topping high."

In all tests, plots topped low alternated with plots topped high, there being four or five repetitions of each treatment. Plots were taken of such size as to make a fair load for a cane car—say three or four tons of cane. Tests were all located, laid out and plot divisions cut on the day previous to burning. After burning, one set of men cut all the topped high plots; another set cut all the topped low plots, gathered all the tops and carried these out of the field. Here the tops were re-cut to remove the seed piece and to check with the practice in the plots topped high. This cane was bagged, weighed and crushed in our "Cuba A" sample mill to obtain a sample of juice for analysis. Areas were obtained by measuring the length of all lines in each plot and by assuming exactly five-foot spacing of lines. The weights of cane and samples of crusher juices were obtained at the mill.

The cooperation of the harvesting staff was largely responsible for the success of these tests.

Table I summarizes the results of crusher juice analyses.

TABLE I

CRUSHER JUICE DATA—ARITHMETICAL AVERAGES

Tests				Plots Topped High				Plots Topped Low				Gain for Plots Topped Low	
No.	Field	Date		Brix	Pol'n	Purity	Q. R.	Brix	Pol'n	Purity	Q. R.	Pur.	Q. R.
1	2 A	Jan.	21	15.64	12.98	82.99	10.79	16.32	13.76	84.31	10.05	1.32	0.74
2	23 C	Feb.	10	18.35	16.30	88.83	8.19	18.68	16.68	89.29	7.95	0.46	0.24
3	23 B	June	3	18.53	16.03	86.51	8.47	18.75	16.40	87.47	8.20	0.96	0.27
4	23 B	June	7	19.43	17.28	88.93	7.69	19.33	17.17	88.83	7.75	-0.10	-0.06
5	A	July	29	17.88	15.22	85.12	9.03	18.13	15.63	86.21	8.70	1.09	0.33
Averages				17.97	15.56	86.59	8.71	18.24	15.93	87.34	8.46	0.75	0.25

With the exception of Test 4, the results of which were unaccountably inconsistent, crusher juices from the plots topped low showed a well substantiated improvement, both in apparent purity and in quality ratio, varying from 0.46 to 1.32 for purity, and from 0.24 to 0.74 for quality ratio. This fact is particularly significant when remembering that the tests were conducted on a practical field basis.

The seed pieces removed from the tops of the plots topped low showed the following data:

Table II

Top Material From Plots Topped Low—"Cuba A" Sample Mill

Tests Number	Tests Field	Brix	Pol'n	Purity	Q. R.	Glucose	Weight, % of Cane as Topped High
1	2 A	8.92	3.70	41.48	195	1.78	4.66
2	23 C	10.53	5.85	55.56	40	......	1.70
3	23 B	9.95	4.35	43.72	116	......	2.82
4	23 B	11.40	5.85	51.32	47	......	3.00
5	A	11.35	5.70	50.22	52	3.30	4.37
Averages		10.43	5.09	48.80	63	......	3.31

The extraction of polarization in our sample mill at the last test was 61 per cent. In all probability, then, if this material were crushed by commercial equipment, the purities would be considerably lower. In all cases, juices were so low in Brix and purity that the quality ratio was not better than the order of 50, reaching a high figure of 195 in Test 1.

The top material from plots topped low was rich in glucose as shown by the ratio $\frac{\text{glucose}}{\text{polarization}} \times 100$. This figure for Test 5 for crusher juice from plots topped low was 6.4 as against 57.9 for the top material as crushed in the sample mill. The influence of this in the crusher juice of the cane from plots topped high was not great, the average for these plots of Test 5 showing 1.07 per cent glucose as against 1.00 per cent for the plots topped low.

There remains the effect of the treatments on the calculated sugar yields. Though juice data were satisfactory, the yields of cane per acre from the various plots showed such a wide fluctuation, that averages do not and indeed cannot be expected to show differences as small as 1.7 per cent to 4.7 per cent. In order to calculate comparable sugar yields, we then assume uniform yields of cane, differing in the plots topped low by the average per cent of material removed by topping low as directly determined by weights. This uniform yield of cane for each test will approximate, in round numbers, the average yields of all the plots in that test. Table III shows these data.

Table III

Calculated Sugar Yields With Assumed Uniform Cane Yields

Tests No.	Tests Field	Tests Date	Plots Topped High: Cane per Ac.	Plots Topped High: Q. R.	Plots Topped High: Sugar per Ac.	Plots Topped Low: Cane per Ac.	Plots Topped Low: Q. R.	Plots Topped Low: Sugar per Ac.	Gain in Sugar per Ac. for Plots Topped Low
1	2 A	Jan. 21	140.00	10.79	12.97	133.48	10.05	13.28	0.31
2	23 C	Feb. 10	120.00	8.19	14.65	117.96	7.95	14.84	0.19
3	23 B	June 3	130.00	8.47	15.35	126.33	8.20	15.41	0.06
4	23 B	June 7	115.00	7.69	14.95	111.55	7.75	14.39	–0.56
5	A	July 29	100.00	9.02	11.09	95.63	8.70	10.99	–0.10

It is significant that the gain in sugar yields for topping low decreased throughout to a definite loss in the latter part of the crop. This will hold true, though the data of Test 4 be discredited, due to fluctuations, the cause of which is not understood. We may expect, then, that as the cane approaches the peak season, as far as juices are concerned, in April, May and June, topping low becomes, at Ewa, a doubtful, if not uneconomical procedure, but that previous to that time, is fully justified, not only in increased yields of sugar, but also, since contracts are based on the tonnage of cane received at the mill, in the reduction of the costs of cultivating, cutting, loading, transporting and milling, eliminating about 3 per cent of all cane which, as far as sugar manufacture is concerned, is virtually worthless.

Summary

Tests instituted to determine the point at which to top cane at harvest under local conditions have shown that it is profitable to top cane so as to remove one seed piece of three eyes only during the early part of the crop. Presumably, as the peak in juice purities (and in the sucrose content of the cane) is reached, the advantage in topping low becomes progressively less, and at the peak period shows a decided loss.

A Practical Method of Using Molasses as a Fertilizer

By J. A. Verret

With the present low market values for molasses a great deal of it is not now marketed. A portion is used as fuel. But many plantations have all the fuel they need from bagasse, so a large part of our molasses is now allowed to run to waste into the sea. A very small portion is run on low fields in irrigation water. A small amount is sold.

With our present crops we produce very nearly 200,000 tons of molasses per year. This molasses contains from about .4 to over 1.5 per cent of nitrogen, .15 per cent to .3 per cent phosphoric acid and from about 2 to 6 per cent of potash.

The total nitrogen, phosphoric acid and potash in our final molasses and their values on the plantations would be approximately:

	Tons	Value
Nitrogen	1,400	$ 406,000
Phosphoric acid (P_2O_5)	500	50,000
Potash (K_2O)	8,000	720,000
Total		$1,176,000

This gives our molasses a net value on the plantation of over $5.00 a ton, without giving a value to the organic matter and lime which it contains.

In Mauritius and in Java, considerable quantities of molasses are used as fertilizer. In Mauritius, molasses is used at the rate of from 4 to 15 tons per acre; some figures we have seen from Java indicate a use of about 10 tons per

acre. It is not considered safe to use undiluted molasses on growing crops, especially in the larger amounts. Molasses in contact with the growing crop can result in serious burn. Also as the molasses ferments and decomposes, denitrification of the soil takes place and plants suffer temporary nitrogen starvation.

Here it may be well to note that the use of molasses in the irrigation water to growing cane should be practiced with caution. We know when molasses is applied to the soil that temporary denitrification takes place. This denitrification is brought about by the cellulose decomposing bacteria. These bacteria absorb the nitrates in the soil and change them into proteins. This organic nitrogen is not lost, but is of no use to the plant until the bacteria die and their protein content is again changed to nitrates. From the above we see that a field could be kept in a continuous state of denitrification by the application of molasses often enough with the irrigation water. All the molasses to be used on a field should be applied in one dose in order to shorten the time of nitrate shortage in the soil. This would indicate that it is bad practice to empty the molasses in a reservoir and use it that way in routine irrigation. The molasses should be put in the level ditches for each field.

The most satisfactory method of using molasses is to apply it to fields about to be plowed in order that the molasses may be in the ground one to two months before planting.

Molasses as such is extremely difficult to handle, and it would not be practical to use it on many of our fields, and very often these are the fields which need it the most.

It would help a great deal if molasses could be made portable. It occurred to some of us that perhaps a mixture of molasses with other mill by-products could be made in such combinations as to allow the mixture to be bagged so that it could be handled in the same way that we now handle press cake and stable manure.

Dr. F. E. Hance, of the chemistry department, and the writer, have been working on the problem. Dr. Hance has been working more with special mixtures for use in poor areas of fields in connection with his "replaceable base" work. Dr. Hance will report on this as the work advances.

We will discuss here work having to do with what might be called the "routine mix" for general use.

The basic idea is to take molasses, press cake and mill ashes in the proportion in which they are turned out by the factory, and adding to this enough bagasse to make a mixture which can be bagged and spread on the field from the bags or by means of a manure spreader. In this way all the molasses, press cake and mill ashes would be used in addition to a small amount of bagasse, about 3 or 4 per cent.

From the Synopsis of Mill Data we find that the final molasses amounts to 3 per cent of the cane and press cake to about 2¼ per cent. We have no data as regards the amount of mill ashes produced. We can arrive at an approximate figure by using the ash content of the bagasse. This varies in different districts from about .5 to .9 per cent. As the bagasse amounts to 22.5 per cent of the cane this will give us an average ash of about .15 per cent on cane. There is

some loss in burning, so the actual amount obtained would be less than indicated above, about 1 pound of ash to 20 of molasses.

With the active cooperation of the Waimanalo Sugar Company the actual mixing was then tried. We used a concrete mixer for the purpose. Of course other forms of mixers would lend themselves better to the purpose, but this worked fairly well.

W. W. G. Moir has informed us that at Olaa Sugar Company they found that for mixing large batches, hand mixing was faster than a concrete mixer. Very likely a fertilizer mixer would work very well. Soil and manure mixers may also serve the purpose. The materials are taken directly as they come from the mill except that the press cake is pulverized and the molasses made very hot.

After several trials the following gave very good results:

PROPORTION OF MIX

Mill ashes	24 lbs.	5.5%
Bagasse	53 "	12.2%
Press cake	147.5 "	33.8%
Molasses	209.5 "	48.5%
Total	434 lbs.	100.0%

This material had the following composition:

Nitrogen	0.40%	8 pounds per ton
Phosphoric acid	0.81%	16 " " "
Potash	2.65%	53 " " "
Lime	1.09%	22 " " "

This mixture compares well in fertilizer value with either press cake or stable manure as shown in the following comparison:

	Molasses mixture	Press cake	Stable manure
Nitrogen	0.40%	0.59%	0.50
Phosphoric acid	0.81	0.61	0.25
Potash	2.65	0.01	0.50
Lime	1.09	0.92	......

The mixture as made amounts to about 7 or 8 per cent on cane. With a yield of 60 tons of cane per acre this would give about 4.5 tons of this fertilizer per acre or 36 pounds of nitrogen, 72 pounds of phosphoric acid, 238 pounds of potash and 108 pounds of lime.

We are trying experiments with this, both in pots and in the field, on fields to be plowed and on growing ratoons. We are especially anxious to try this on some of our poorer acid mauka fields where it is not now practical to apply molasses.

The Olaa Sugar Company has done some work along these lines. They found that the following amounts gave a nice material easy to handle:

Molasses	1000 pounds
Press cake	600 "
Mill ashes	100 "
Bagasse	300 "

They have put in large field tests with this material, which had the following composition:

		Pounds per Ton
Nitrogen	0.78	16
Phosphoric acid	1.74	35
Potash	1.48	30
Lime	1.74	35

The Experiment Station is anxious to try this on as many plantations as possible in order to get conclusive evidence as to the value of these mixtures. We would be glad to cooperate in making trial mixes and in putting in field tests.

Molasses as a Fertilizer*

By W. W. G. Moir

The general interest in the utilization of molasses and other sugar by-products as fertilizers has prompted the writer into a discussion of a few of the articles that have been published upon this subject in the past, together with the application of some of the more recent research results to their conclusions.

A short historical sketch of the use of molasses as a fertilizer may be found in Bulletin No. 28 (General Series) of the Department of Agriculture of Mauritius on "The Application of Molasses as a Fertilizer to Cane Soils in Mauritius." The practice originated at about 1860, but did not become general until about 1900 and "is now part and parcel of recognized planting practice in Mauritius."

In Mauritius, molasses is applied either to the land before planting or to the interlines in ratoon areas. Sometimes it is mixed with ash and sugar scums before application. In the slower growing districts it is applied to the interlines even in very small plant cane. But in the plant field it is usually applied several weeks before planting, as molasses applied close to young cane has resulted in killing the young plant. The benefits from this application usually show up first in the plant crop and continue to do so for several crops. The applications are usually from 4 to 15 tons per acre:

Regarding the benefits to be derived from applications of molasses, it is commonly believed that on a cycle of one crop of virgins and five succeeding crops of ratoons, the gain in yield to be ascribed to applications of molasses amounts in the aggregate to as much as 20 tons per acre.

In Hawaii, we have not yet adopted as a general practice the utilization of this by-product as a fertilizer in our cane fields. Many plantations have run their waste molasses into the sea when there has been no market for it, while others have placed it in the irrigation ditches and continuously irrigated a limited, usually very fertile, area with this water-molasses solution. In spite of these continuous heavy applications of molasses no decrease has been made in fertilizer applications to these fields. From what has been shown in results obtained in Mauritius and

* A paper presented at the Forty-seventh Annual Meeting of the Hawaiian Sugar Planters' Association, Honolulu, November 16-21, 1927.

which are later reviewed in this article, this practice should be an unremunerative one if not detrimental.

We have records of heavy molasses applications to growing cane or stubble causing the death of the plants and still other data showing a marked stimulation in the growth. The texture and moisture content of the soil have much to do with the results obtained. With the open, coarse textured soils found in the majority of fields of Hawaii little harm can be expected even up to a 40-ton per acre application, while on the finer silts and heavy clays complete killing out should be expected from applications of half that amount. A remedy for the latter situation is to irrigate immediately after the application of molasses. Molasses has been applied to the kuakuas (interlines) in newly planted fields at Olaa without detrimental effects, and even on stubble at the rate of 40 tons or more without any killing or checking in growth becoming noticeable. In heavy, poorly drained soil in which molasses has been well plowed in, a checking in the growth has been noted if the application has been made within two or three months before planting. But following a period of two or three months from planting, a stimulation in growth has been noted.

The first systematic experiments to test the manurial effect of molasses on cane were carried out in Java in 1903 and 1904. In some of these the cane was killed, in others there were negative results and in still others increase in yield.

The result of the work of Boname at the Station Agronomique in Mauritius in 1909 may be tabulated as follows:

	Metric Tons Cane		Gain Due
	Molasses	No Molasses	to Molesses
No fertilizer	19.34	18.99	1.65
No nitrogen	29.43	24.27	5.16
No phosphoric acid	27.67	26.26	1.41
No potash	33.60	29.44	4.16
Complete fertilizer	35.05	30.27	4.78

These are averages of four crops from the same area. The molasses used was 5 tons per acre before planting. Mauritius soils are normally low in phosphates and one can easily see how this deficiency has affected the yields. It will also be noted that the plots receiving no nitrogen and no potash are not materially affected because molasses supplies these elements in abundance. If one considers only the returns of the plant crop greater differences will be noted.

	Metric Tons Cane		Gain Due
	Molasses	No Molasses	to Molasses
No fertilizer	28.32	26.28	2.04
No nitrogen	45.84	34.44	11.40
No phosphoric acid	33.60	29.16	4.44
No potash	45.62	33.96	11.66
Complete fertilizer	46.40	36.36	10.04

It will be seen from these figures that on the plant crop 5 tons of molasses added to the complete fertilizer doubled the gain of the complete fertilizer over no fertilizer. This 5 tons of molasses application added 200 pounds of potash and 35 pounds of nitrogen.

The results of the experiments in Java in 1909 are reviewed in the *Hawaiian Planters' Record* of September, 1910, page 130, and also in the Mauritius Bulletin No. 28. Molasses was applied one month before planting and gave increases in yield amounting to 10 tons of cane per acre.

In the Mauritius Bulletin, we find the following gains for two crops of molasses over no molasses on soils equally treated with pen manure and with different fertilizers:

GAIN IN TONS CANE PER ACRE FROM 5 TONS MOLASSES OVER NO MOLASSES.

		Plant	Ratoon	Total
1.	Nitrate of soda...............	8.7	6.2	14.9
	Guano phosphate			
	Sulphate of potash			
2.	Nitrate of lime	7.3	0.5	7.8
	Guano phosphate			
	Sulphate of potash			
3.	Nitrate of soda	8.6	12.2	20.8
	Nitrate of potash			
	Guano phosphate			
4.	Sulphate of potash	15.6	14.5	30.1
	Guano phosphate			
5.	Nitrate of soda	19.0	10.6	29.6
	Nitrate of lime			

The biggest gain being obtained where no nitrates were applied.

In a second series of tests in 1920-21 further proof of the benefit of molasses is given:

On the weighted mean of the two series of experiments, the application of 20 tierces of molasses per acre (5 tons) has given rise to an increase of 9.65 tons of cane per acre in virgin cane (plant).

This 5-ton application of molasses has applied about 31 pounds nitrogen, 16½ pounds P_2O_5 and 121 pounds of potash. Their soils are very deficient in phosphates and low in potash, but these amounts added should not account for these gains in cane yield.

In the *Hawaiian Planters' Record* of July, 1927, will be found an abstract of this Bulletin, No. 28, from Mauritius.

At Pioneer Mill Company, molasses has been very satisfactorily applied to areas to be plowed and planted by irrigating the old furrows with a mixture of molasses and water. Varying amounts have been applied on different level ditch size plots and the cane from this experiment will be harvested this coming crop (1928). Observations on the growth of cane on these plots have shown that the cane on the molasses plots has consistently outgrown that on the check plots. The difference between the 40-ton molasses application and the check is extremely more marked than that between the 10-ton and check plots.

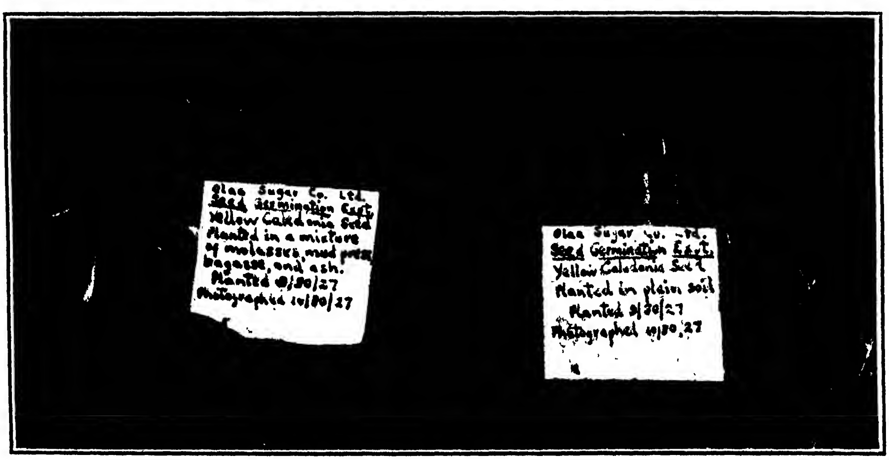
In another area at Pioneer, a part of a field of a few acres in extent was given an extremely heavy application of molasses when it was fallow. A few months later it was plowed and planted. The adjoining section of the field, as well as the

molasses area, had a heavy application of mud press and the whole field a heavy fertilization. No differences were noted in yield between the different parts of this field at harvest, the whole yielding at the rate of 90 tons per acre. The plantation was unable to take care of the ratoons except for an occasional flooding irrigation and one application of fertilizer for four or five months after harvesting in June, 1924, due to the labor strike. The weeds were very heavy in the whole field but the cane on the molasses area continued to grow. The whole field was treated uniformly and at harvesting in 1926 the molasses area yielded as much as the plant crop and twice as much as the adjoining area upon which molasses had not been applied.

In 1922, in an experimental layout at Pioneer Mill Company in a field adjoining the two areas just mentioned, molasses was applied at the rate of 2 tons per acre to plant cane about 1½ to 2 feet high. The molasses was applied by buckets to the sloping side of the kuakua on the upper side of the cane row. Two amounts of nitrogen treatments were also included as variables in this experiment and the results obtained in 1924 are given below:

	T. C. A	Q. R.	T. S. A.
90# of N. + 2 tons molasses per acre.........	61.1	6.62	9.24
90# of N.	58.4	6.62	8.83
180# of N. + 2 tons molasses per acre........	71.3	6.95	10.25
180# of N.	71.6	7.00	10.23

The molasses analyzed as follows: 0.65 per cent N, 5.44 per cent K_2O and 0.16 per cent P_2O_5. Molasses with the smaller amount of nitrogen gave a gain of .41 ton sugar per acre over the no-molasses. This gain in the low nitrogen plots was very definite in that in all cases the molasses plots were better than the adjoining no-molasses plots (four repetitions of each). With sugar at $90 a ton a gain of .2 ton of sugar for each ton of molasses added, we would have a gross return for one ton of molasses of $18. The applying of one or two tons of



A test showing the influence on germination from an application of a mixture of molasses, mudpress, bagasse and ash. The larger shoots on the left were treated, those on the right were untreated. The cane was planted September 30, 1927, and photographed October 30, 1927.

molasses in irrigation water would not amount to more than about $3 per acre. This would still leave a net return for molasses as a fertilizer of about three times the net return for the sale of molasses.

The lack of difference in yield when the molasses and check plots both got 180 pounds of nitrogen and the increase in yield of the molasses plots over the check plots when both got 90 pounds of nitrogen, would make it appear that part of the nitrogen added to the molasses plots in the 180 pounds dose was unremunerative and could have been saved.

Molasses has been very satisfactorily applied at the rates of 9 tons and 18 tons per acre on the unirrigated lands of Lihue before plowing by means of a large tractor-drawn dump wagon with valve gates to regulate the flow of molasses. Tank cars have been emptied into the dump-wagon very rapidly by the use of compressed air. The easiest method of applying molasses seems to be through the irrigation water, and many plantations have been successful in applying large doses without any harmful effects to the standing crop.

From an article in the October, 1927, *International Sugar Journal*, abstracted from the "*Sugar Supplement of Tropical Agriculture*," the following quotation is copied:

A a fertilizer molasses has found favor in Mauritius and Java. According to certain figures of increased production, the net value realized was 2⅓ cents per gallon, on a conservative basis.

Taking 167 gallons as equal to a ton of our molasses this would represent $3.90 net value of one ton of molasses as a fertilizer. This is much more than the net return for a ton of molasses at the plantation at the present time. It is also a rather low figure in view of the results obtained at Pioneer and the observations on the stimulation of the ratoon crops for several cuttings.

Peck's work on the effect of molasses on ammonification, nitrification and the denitrification of nitrates in lysimeters and in beakers, has long been a point of controversy in the use of molasses in Hawaii. He concluded from his first tests in glass beakers that (Exp. Sta., H. S. P. A., Bulletin No. 34):

(1) Molasses applied at intervals on land on which cane is growing and fertilizer has been applied will work harm by destroying nitrates already applied or by preventing the formation of nitrates from other sources of nitrogen supplied in the fertilizer. (2) Molasses applied to land lying fallow or at an interval of several weeks prior to the planting of the crop may produce beneficial results by providing a stimulus to the nitrogen fixing bacteria of the soil, and thereby adding a store of nitrogen to the soil in a form which can be made readily available to the crop at a later date by the other organisms in the soil.

In the second series of tests in lysimeters (Exp. Sta., H. S. P. A., Bulletin No. 39):

The general conclusion is that the results of experiments with soil in small containers, as given in Bulletin No. 34 of this Station, are substantiated.

Molasses applied to land which is receiving the usual fertilizer applications as practiced in these Islands will work harm by causing a part of the nitrogen applied as nitrate to revert back to less available or unavailable forms of nitrogen; by checking the nitrification of sulphate of ammonia dressings; and by retarding the ammonification and nitrification of the nitrogen of organic fertilizers.

The harmful effect of molasses dressings is due entirely to the organic constituents of the molasses, the mineral matters having no influence.

Dressings with carbonate of calcium do not correct such adverse action of molasses.

These lysimeter tanks, studied for only five months. had no crop growing upon them, and, therefore, are not comparable to field conditions. It would be well worth anyone's time to read over this bulletin and study the tables of figures given as well as the conclusions drawn. The maximum amount of molasses used was but two and a half tons of molasses per acre. It is certainly remarkable that this small amount of molasses was so efficient in tying up a large part of the nitrogen and preventing the leaching of it into the drainage water. This represents an application of plant food of 13 pounds of nitrogen, 8.6 pounds phosphoric acid, and 272.6 pounds of potash per acre. The molasses was applied two weeks before the first irrigation in the series of lysimeters, receiving one application of 400 gallons per acre, while in the other series molasses at the rate of 40 gallons per acre was applied at each irrigation. The different forms of nitrogen at the rate of 100 pounds per acre were applied one week before the first irrigation, and the lime carbonate two weeks before.

From our present knowledge of the effect of molasses and lime, we can be reasonably certain that these were not applied long enough before starting, nor were the tests carried on long enough. If the irrigations applied to these tanks represent normal field applications every two weeks, and the amounts of nitric nitrogen secured in the drainage in these tanks represent field conditions, we certainly should be thankful that as small an application of molasses as used in these tests should be able to conserve this outflow of valuable nitrates to as much as 15 per cent during a five-month period.

Does this not suggest the use of molasses in irrigation water during the fall and winter months so that the normal rains will not leach out nitrates and still have them become available at a later date? And does this not suggest the possibility of applying most of the nitrogen to your fields in the first few months of growing and then by irrigating with molasses water for a short period, both to conserve the nitrogen, and to prolong the good effects of early stimulation of growth? This would create a natural storehouse of nitrogen in the soil upon which the plant would draw instead of waiting for a "shot" of nitrogen.

There are several points of interest in these tables of Peck's, a few of them being the increased amount of mineral matter in the drainage from tanks treated with fertilizers, and especially sulphate of ammonia; the increased amount of chlorine, lime and magnesia in the drainage in molasses treated soils; the increased alkalinity in molasses treated soils; and the very small amount of potash in the drainage due to the application of molasses. These tables are well worth a closer study than my time and space here permit.

In the *International Sugar Journal* for August, 1927, will be found an abridged printing of another bulletin published by the Mauritius Department of Agriculture on "The Reversion of Nitrates in the Soil under Cultural Conditions in Mauritius." The results of experiments conducted there

"have shown that when artificial nitrogenous fertilizers are applied to cane lands, which have already received dressings of organic manure and molasses, little or no effect is frequently observed. . . . In Mauritius the application of artificial nitrogenous manures is widely practiced, and the net result of these investigations is to show that a considerable part of the artificial manures so applied may very probably be unremunerative. This result is

of profound importance to the sugar industry and should receive the most careful attention of all planters.

The conclusions drawn are:

(a) Under the conditions in which this investigation was carried out, the application of large amounts of molasses caused nitrification to be arrested, and causes ammonium compounds to become converted into organic nitrogenous compounds.

(b) Nitrates which are present in the soil are, on the addition of large amounts of organic matter to the soil, reverted to less readily available forms. Molasses causes the greatest loss in nitric nitrogen, dried green manure and dried farmyard manure following in the order named.

(c) Molasses and dried green manure do not seem to cause any increase in the loss of nitrogen in the gaseous form, whereas with farmyard manure a big increase in this loss occurs.

The results reported by this Mauritius Bulletin were obtained from a study of small quantities of soil, approximately 4½ pounds in each treatment, placed in glass jars with 250 c. c. of water, and treated with various materials. The figures were obtained for the various forms of nitrogen at the start and again at the end of the experiment ten months later. The gain (+) or loss (—) in grams during the ten-month period are given below:

	Ammoniacal	Nitric	Organic	Total
Soil	+0.021 grs.	+0.007 grs.	+0.038 grs.	+0.066 grs.
Soil + Molasses	+0.043	—0.007	+0.065	+0.101
Soil + Sulphate of Ammonia.	—0.753	+0.695	+0.111	+0.053
Soil + Sulphate of Ammonia + Molasses	—0.646	+0.191	+0.450	—0.005
Soil + Nitrate of Soda......	+0.014	—0.189	+0.215	+0.040
Soil + Nitrate of Soda + Molasses	+0.102	—1.148	+0.996	—0.050

It should be noted from the figures above that the molasses alone has increased the total nitrogen in the soil more than any other treatment; that the soda and ammonia have added to the total nitrogen of the soil less than the soil alone, and that when molasses was combined with these nitrogen fertilizers there was an actual loss of nitrogen which was much more marked in the soda treatment.

It certainly appears from the reading of this bulletin that but a single jar was used for each experiment, with none of the experiments repeated. In the second series of experiments two jars were similarly treated as the two in the first series, and below is given the grams gained or lost, to show what large differences were obtained in the two cases.

	Nitrogen			
	Ammoniacal	Nitric	Organic	Total
Series 1 #5 (10 months) Soil + Soda..	+0.014	—0.189	+0.215	+0.040
Series 2 #1A (10 months) Soil + Soda.	+0.067	—0.092	—0.250	—0.275
Series 2 #1B (14 months) Soil + Soda.	+0.057	—0.025	—0.546	—0.514
Series 1 #6 (10 months) Soil + Soda + Molasses........................	+0.102	—1.148	+0.996	—0.050
Series 2 #2A (10 months) Soil + Soda + Molasses.......................	+0.278	—0.984	+0.365	—0.341
Series 2 #2B (14 months) Soil + Soda + Molasses	+0.301	—0.989	+0.366	—0.322

In all these experiments 2 kilograms of soil, 250 c. c. of water and 7.5 grams of nitrate of soda were used, while in the ones treated with molasses 60 grams were added. One thing these figures show clearly is the greater and quicker loss of total nitrogen in the soils treated with soda alone than in those that had molasses in addition to the soda. This undoubtedly is one of the reasons why molasses applied to the fields has had such a lasting stimulation. It will also be noted from these figures that the organic nitrogen is being stored in greater quantities for future use where molasses has been applied.

In the general discussion of results it is mentioned that in the mixture of molasses with either green manure or farmyard manure there is less loss of nitric nitrogen—molasses alone caused 72.9 per cent to revert; molasses and green manure 53.8 per cent; and molasses and farmyard manure 63 per cent.

According to Doryland, addition of a small percentage of sugar lowers the ammonification and, therefore, of necessity, lowers nitrification. In this case it seems that the bacteria of the soil have first of all derived the energy necessary for their existence by means of oxidizing the readily available organic material, i. e., the molasses. When this source of energy is completely finished the bacteria may derive their energy from the ammonia or nitrates already existing in the soil. According to Thornton, when a nitrogenous source of energy predominates, ammonia is released; but when a non-nitrogenous source predominates, it may be assimilated. In the experiments under discussion it is seen that when a large quantity of molasses is added to the soil, it has the effect of causing the disappearance of large amounts of nitrates.

Mauritius soils are high in organic matter, and every attempt is made to return cane trash and pen manure to the fields as well as molasses. Although nitrogenous fertilizers are added later, there is practically no response to them. In considering these results one must realize that there may be more than one way of loss by denitrification.

First of all it consists of the process whereby nitric nitrogen is converted into organic nitrogen, i. e., the reverse of nitrification; secondly, it also comprises the process in which nitric nitrogen is set free to the atmosphere as gaseous nitrogen, i. e., the reverse of nitrogen fixation. Thus it is quite possible that although the denitrification caused by two different manures may be the same in quantity, yet the final products may be vastly different. Addition of molasses or a dried green dressing does not seem to have increased the loss in total nitrogen; it would seem, therefore, that the action of these manures is to bring about a reversion of nitric nitrogen to an organic form, not to set it free as gaseous nitrogen. This may be an important point in the conservation of the soil nitrogen, as nitrogen reverted to the organic form is not lost, but merely rendered unavailable for a certain length of time, whereas a total loss occurs when gaseous nitrogen is evolved.

This is very important and should be kept in mind in reviewing the work done by investigators who have claimed that molasses was detrimental when applied to the soil. If nitrogen is stored as organic nitrogen in the soil due to the addition of molasses, we have a ready supply upon which the plant can draw at a later date. Even if nitrogenous fertilizers are applied to this same soil sometime after a molasses application, we can be fairly sure that the excess will not be leached from the soil, but stored for future use by the plant. Is this not a better practice to follow, where the plant gets its nitrogen from a natural storehouse than where it gets it through a scheme by which man flatters himself that he knows when the plant will require it?

It is unfortunate that such detailed work as that carried on by these Mauritius investigators, and by Peck in Hawaii, should not have included several repetitions of each treatment and also have included actual field study with crops growing upon the several treatments. If we were to entirely accept the results obtained through these experiments, we should conclude that molasses caused a loss of nitrates in the soil during a certain period after application, and that it was detrimental and should not be used. But from observations and experimental data we know that molasses gives a stimulation to growth with increased yield, and that this stimulation is very often noticed within a very short period after application to the standing crop. Therefore, there must be a difference in conditions between soils in jars and soil in the field to account for these different results.

In the several articles on work done in Mauritius and at Rothamsted, it has been pointed out that the molasses should be applied sometime before the planting of a crop. During this period the denitrification processes will probably be completed. Nitrification has been arrested mainly due to the conversion of all the ammonia into organic nitrogen. After a certain period of time ammonifying and nitrifying bacteria are stimulated into greater activity and render the stored organic nitrogen into nitrates for the use of the plant. Besides this rendering of the nitrogen available by these bacterial activities, there is a liberation of plant foods from unavailable reserves and an improvement of physical conditions in the soil. Nitrogen fixing bacteria are greatly stimulated by the addition of molasses or such easily oxidizable carbohydrates which they use as energy to complete their life processes. If the soil is rich in nitrates they will utilize these nitrates instead of taking nitrogen from the air, thus becoming harmful instead of beneficial. This is probably what becomes of nitrates when applied to areas recently treated with molasses, or when molasses is applied in every irrigation made to a field that has had heavy nitrate applications.

Many factors, such as texture of soil, organic content, and microbiological activity, control the length of this period of denitrification, but from an observation of conditions in Hawaii it would appear to be very short.

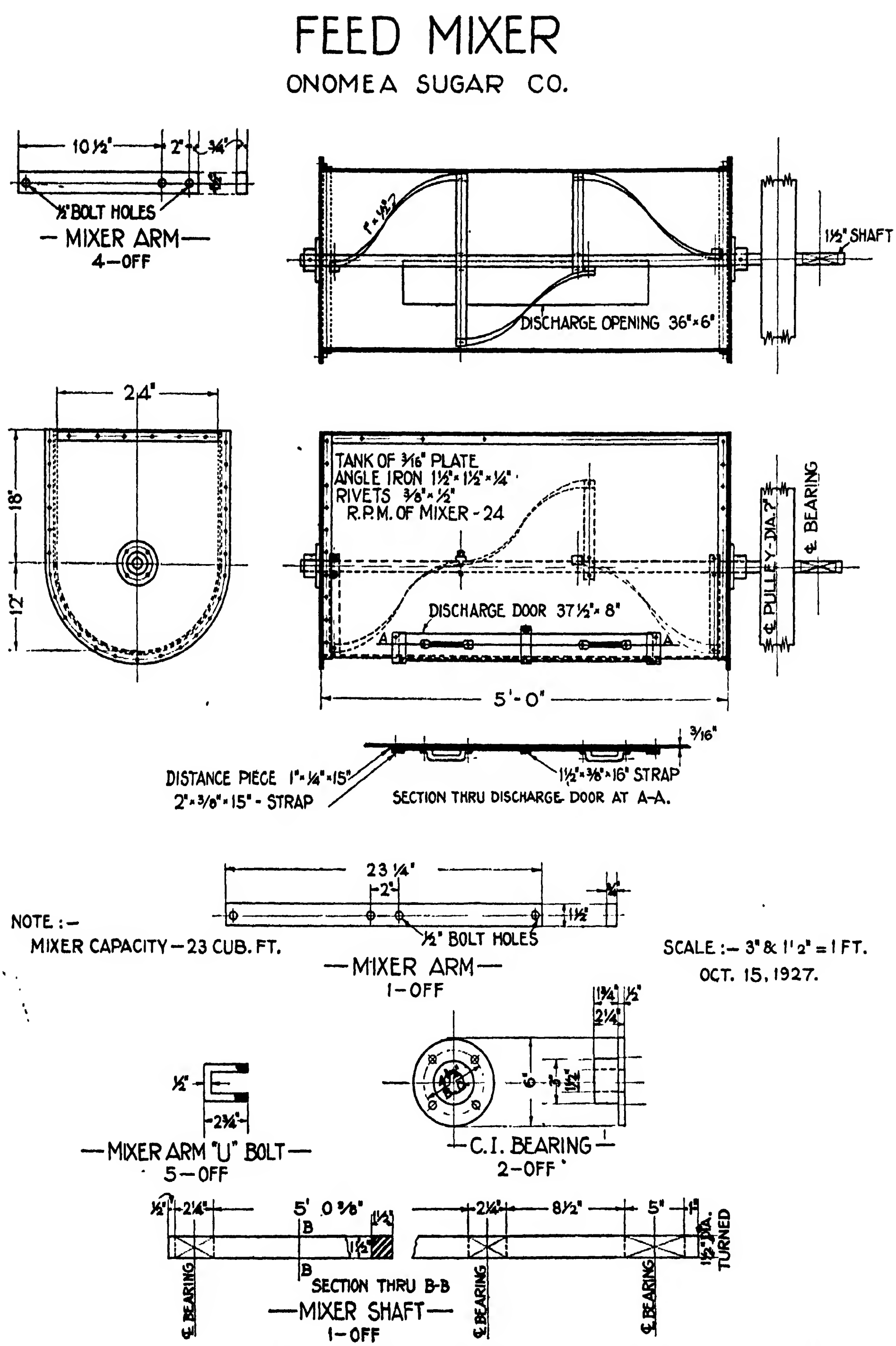
In the *Hawaiian Planters' Record* of June, 1911, was reprinted the results of an interesting test in South Africa which is repeated here:

TONS PER ACRE (CANE)

	Plant	Ratoon	Total
1. Complete fertilizer 50#N—70#P_2O_5—50#K_2O per acre.	34.1	28.3	62.4
2. Same + 600 gals. molasses per acre (3.6 tons)	42.5	31.6	74.1
3. 400 gals. molasses (2.4 tons), 1 ton press cake, ½ ton bagasse ash	40.2	33.8	74.0
4. Nothing	24.6	17.2	41.8

It will be noted that treatment 3, utilizing only by-products of the industry, gave about the best results.

This brings up the subject of a mixture of by-products or the application of any one of them to our fields in place of the purchase of commercial fertilizers. This is at the present time of great interest to many plantations and much experimentation is going on. Next year at this time we should have some very inter-



A feed mixer which offers possibilities of usefulness in preparing a mixture of the by-products: molasses, mudpress, bagasse and furnace ash.

esting data to present on this subject. Much to the surprise of many people a mixture suggested by members of the Experiment Station staff utilizing molasses, mudpress and mill ashes, in proportion as they are produced each day at the factory, plus an amount of bagasse, less than 3 per cent of the daily output, will make a mixture finer in texture and as easily handled as farmyard manure. Experiments on amounts to apply per acre on ratoons and plant are under way at present. Preliminary observations of some of these tests show that seed planted in this mixture in the bottom of the furrow without mixing it with the soil, but covering over the whole with soil, has germinated a week sooner than seed planted in ordinary soil. The week earlier germination has resulted in greater growth to date. Applications of this mixture at rates of 20 and 40 tons per acre immediately on the stubble after mixing have not only acted as a mulch in keeping down weeds, but has stimulated the ratoons into greater stooling of a greener color than where no mixture was applied. There is a generation of heat in the mixture a short time after mixing, which helps considerably in stimulating growth. The analysis of this material is quite variable depending upon the amounts of each material used and the plantation considered.

The addition of phosphates or potash to bring up the amounts per acre in very deficient areas should be easily accomplished. Here we have a natural by-product fertilizer which should cost very little per ton to mix on the plantation, and which will more than likely replace all of the fertilizer now applied to many of our poor upland fields as well as supplement or replace much of the fertilizer on the better lands.

From the many profitable returns from molasses applied to land in other countries for a good number of years and from the many indications of its value here in Hawaii during the last few years, it seems like a tremendous waste of a profitable by-product not to apply it to our lands. This latest mixture mentioned above offers a simple means of returning to our land the greater part of what the crop removed from it while growing. Many minute amounts of certain elements necessary to good growth and about which we know very little will also be returned, insuring continued fertility.

We can, therefore, conclude from this discussion that:

(1) Molasses as a fertilizer is extremely beneficial to yields, the stimulation lasting over several crops.

(2) A certain period of time should elapse between the time of heavy applications to certain soils and time of planting.

(3) Lighter applications can be made with safety to growing canes through irrigation water, and on the interlines when applied without dilution.

(4) In unirrigated areas heavier doses may be applied to the interlines with safety even on newly planted areas.

(5) A mixture of by-products—molasses, mudpress, bagasse and ash—will be even more beneficial and probably a more economical method of applying molasses.

(6) Better results are obtained from molasses when nitrate fertilizers are left off or only light applications are made.

What the gain from these applications of by-products may be due to is still an open question, but that we get the increased returns is beyond a doubt. Whether the molasses causes a partial sterilization of the soil and a later stimulation of nitrification, whether the nitrogen-fixing bacteria are greatly stimulated, or plant foods are made more available, or nitrogen stored for use over a longer period of time, or the soil solution and soil in general made more alkaline, remains to be proven.

One of the things that was most outstanding to me at the recent Washington meeting of the Soil Congress was the great amount of interest taken in the subject of Organic Matter and Microbiology of the Soil. Since this matter I have been discussing is on this very subject, and so little has been done in Hawaii on the study of these operations in the soil, and since by the slightest improvement of conditions for greater microbiological activity we can have a vast army working for us without wages, I feel that it should be strongly recommended to the Trustees of the Hawaiian Sugar Planters' Association that a department of microbiology be created at the Experiment Station to study these matters, and that a trained microbiologist of good standing be employed to head this department.

Power Salvage*

By J. P. Foster

I have been requested to write a paper upon the subject of power salvage, meaning the power which may be derived from the useful expansion of steam required for heating purposes in our sugar factories. The same process could just as correctly be called heat salvage, depending upon the viewpoint.

If our primary object is to obtain heat, as in the boiling house, then we may obtain power as a by-product. If, on the contrary, our primary object is to obtain power, then we may obtain heat as a by-product.

Given a definite amount of evaporation to accomplish in the boiling house, with power as a salvage product, we know what type and size of engine to install, and we can closely estimate the amount of power we should be able to obtain, under favorable conditions. Note particularly the qualifying term, "favorable conditions." Each factory is an individual problem for which we have no empirical solution. Some sugar factories may be capable of a high salvage in power, others less than half as much. For the present purpose, I will consider that a factory should produce, as by-product power, not less than 25 k. w. of power per ton of cane ground. Such a factory I would rate at or near 100, consequently a factory capable of producing but 12½ k. w. would rate 50, from a standpoint of efficient power salvage. Assume that we are now about to make a survey of an old sugar

* Presented at the Sixth Annual Meeting of the Association of Hawaiian Sugar Technologists, Honolulu, October 17-20, 1927.

factory with the object of determining what changes, if any, will need to be made in order that its salvage of power shall approach the maximum.

First of all we will look to the back-pressure, and consider means for reducing it, and we will examine the continuity and regularity of steam consumption, and see what can be done to smooth it out. We may find the back-pressure anywhere from 5 to 10 pounds or higher, and that the mill staff believes the equipment of the factory to be such that a reduction in back-pressure cannot be obtained without practically rebuilding the factory at an unjustifiable expenditure.

They believe that the same results may be obtained by raising the initial pressure. In other words, they will obtain by this means the same mean effective pressure as the more fortunate factory where low back-pressure is possible. This cannot equalize, for the M. E. P. does not work out at all in this case, unless we increase the initial pressure 5 pounds for each 1 pound increase in back-pressure. This is shown by the subjoined table of approximate effective equivalents, giving the increase in initial pressure required to compensate for increased back-pressure, assuming the cut-off to be constant.

Approximate Back Pressure (Gauge)	Equivalents Initial Pressure (Gauge)
0 lbs.	100 lbs.
1 "	106 "
2 "	112 "
3 "	118 "
4 "	124 "
5 "	130 "
6 "	136 "
7 "	142 "
8 "	148 "
9 "	154 "
10 "	160 "

From this it will be seen that raising the initial pressure to overcome the handicap of high back-pressure may be even more expensive than a partial renovation of the factory. One frequently hears the salvage power plant spoken of as one of "non-condensing operation." This is not correct unless the steam exhausts into the atmosphere. What happens is that the usual power house condenser is replaced by condensers of various types, shapes and sizes, located in different parts of the factory. There will be condensers functioning as juice heaters, condensers functioning as evaporators, and other condensers serving as vacuum pans. The latter are intermittent in operation instead of continuous. Inasmuch as the back-pressure will be a principal factor in the operation of the power unit, we must see that the condensers are correct.

Three things are essential in the design of a condenser:

1st. Sufficient pipe and inlet area to get the steam to and into it.

2nd. Sufficient cooling area to effect condensation.

3rd. Sufficient outlet and pipe area to carry away the condensate.

Please notice that in the second essential we are not thinking in terms of heating surface, but the contrary, cooling surface. In most, if not all factories, the

surface is fixed, and changes must be made to get the utmost efficiency out of the cooling surface available, and first it is necessary to get the steam up to and into the condenser. Very little if any of our older apparatus was originally designed for low pressure operation. Steam or vapor inlet areas were invariably made too small, and the piping, naturally, was the size of the inlet. If the steam inlet was correctly designed for 10 pounds pressure, we must increase the area 66 per cent for operation at atmosphere, and 100 per cent for operation at 5 inches vacuum. There will be many instances found where the cooling surface could readily condense much more vapor than is supplied to it.

In all probability it will be found, however, that the greatest improvement can be made in the drainage. In the older types of apparatus there was almost never sufficient provision made for drainage, and it is also a fault in most of the more modern apparatus, which is always accentuated where pressure approaches atmosphere. The designer knows that the volume of a pound of steam varies with its pressure, and makes suitable provision for the increased volume.

He then often makes a mistake and figures that a pound of steam condenses to a pound of water, and makes the drainage areas accordingly. Actually, there may be two or more pounds of water to each pound of steam, for we are dealing, not with ordinary saturated steam, but with what we may term super-saturated steam.

There is ordinarily a considerable amount of condensation in the steam lines, and that condensation will often concentrate in certain lines, which, if used as supply lines for condensing apparatus, will result in far more than the calculated water due to the steam entering the condenser.

Much of this water may be entrained, that is, carried in suspension by the steam, so that ordinary bleeders or drain pipes are of little avail.

The drainage trouble is usually worse where the inlet pipes are of insufficient area, as then the steam velocity is correspondingly greater, resulting in more water being carried by entrainment, as well as more being swept along the pipe surfaces. A good rule to follow in drainage problems is to make sure that you are right. Then double the area, and you will be nearer right as well as safer.

Taking the three condenser essentials in the order of their importance and inversely in the order of their cost, we have drainage, steam supply, and cooling surface. Due to the much smaller areas of the pipes, the drainage can be increased very easily and cheaply. The steam supply lines are more expensive to install, but do not ordinarily offer great difficulties, particularly as riveted sheet steel can be used to advantage on the large sizes. I previously stated that the cooling surface is not usually capable of increase. This, of course, does not refer to the installation of additional apparatus, but to the fact that, while we may pipe more steam to a heater or an evaporator, and can pipe more water away from it, we cannot readily increase its cooling, or condensing area. This does not altogether apply to vacuum pans, however.

The old type coil pans should be changed to calandria pans, and many of the earlier calandria pans may, with advantage, be provided with greater areas.

Generally speaking, areas of less than 1½ square feet to the cubic foot of massecuite could be advantageously increased. The expense of so doing is not

necessarily great, for steel tubes and sheets are not expensive, and can often be readily constructed on the plantation if the flat sheet type is used. If correctly designed for circulation they will be found to be very satisfactory.

This statement will probably be challenged on the grounds of alleged short life and alleged low efficiency. As to the life of the steel, such a calandria has been in use at Paia for over ten years and is apparently good for as many more. If massecuites are sufficiently acid to attack the steel, the loss of a calandria will be an insignificant part of the total loss. With regard to the efficiency, the criticism is based upon the lower co-efficient of heat transmission as compared to copper. In this respect it must be remembered that the heat receptivity of a sugar solution decreases very rapidly as its concentration increases. A 60 per cent syrup or a massecuite cannot absorb heat as rapidly as a steel tube can transmit it, so that the limiting factor is not the capacity of the tube to transmit the heat, but rather the capacity of the strike to absorb it.

For example, the heat receptivity, or thermal capacity, if you will, of juice entering the first cell of the evaporator will be about .93; entering the second cell, .84; entering the third cell, .73; entering the fourth cell, .62; and entering the pan, .41; while the average over the duration of the boiling of the strike will be .23.

From the above it would seem that not only the pans, but also the third and the fourth cell calandrias could be profitably made of steel, and possibly the second cell as well.

However, if one wishes to pay for a higher co-efficient of transmission than can be utilized, I have no further argument in that respect.

Having now gone over all of our condensers, and corrected, where possible, the deficient steam supply and the inadequate drainage, we will next see what can be done to get rid of peaks and valleys in our steam consumption curve.

Obviously, if a constant power load is being carried, up to the full steam requirements of the factory, there are but two alternatives to avoid exhausting steam to the atmosphere. If the steam demand is fluctuating widely, we must have, to furnish power during periods of depressed steam demand, a conventional full condensing equipment, with reduced live steam for make-up during periods of maximum demand; or else we must make the demand practically uniform.

By fluctuating demand I do not mean periods when the mill is shut down for any cause, but fluctuations due to the boiling house requiring greater or less amounts of steam during normal operation of the factory. It is assumed that the demand of the heaters and evaporators will be practically constant, and that such large fluctuations as may occur will be due entirely to pan operation.

A pan going off or going on will naturally cause a sharp variation in steam demand, and the only way in which this can be equalized is by careful planning of the pan cycles so that they may overlap. If, for example, we have four pans, a little care and forethought in the boiling house can so arrange the pan cycles that the steam demand becomes practically constant. Close cooperation between pan floor, power house, and the boiler room can go far towards making a bad condition tolerable, and its lack will most certainly make an otherwise favorable condition intolerable.

A signal system should be installed by means of which the pan men notify both the power house and the boiler room of impending changes in the load. Such a system is now in use at Paia. There is in each, power house and boiler room, a signal board equipped with a large electric gong and numbered red and blue lights.

Five minutes before starting any pan, the pan man throws a switch on that pan. A gong rings simultaneously in both power house and boiler room. The operators then look up to the signal board and see a red light on a certain number and both know that the pan of corresponding number will start in five minutes.

Five minutes before stopping a pan, the switch is again thrown, the gong rings, the red light goes out and a blue light appears. By this means both power house and boiler room not only have ample notice of changes and can arrange accordingly, but a glance at the board shows them what pan load is on and they can easily anticipate changes long before they occur. Also, the changing lights show if the pans are being properly overlapped or not, and attention is directed to an unsatisfactory manipulation. If there is lack of cooperation, no amount of skill on the part of the power house operator can avoid fluctuations in back-pressure.

A sudden and unexpected drop in the steam demand will result in a sharp rise in back-pressure, which will cause the power house to consume more steam and consequently cause higher back-pressure due to the vicious cycle at once set up.

To show the effect of this upon the generating unit, we will assume it to be a 1000 k. w. 80 per cent p. f. Cross Compound Corliss unit carrying constant full load with 100 pounds initial pressure, the steam consumption in pounds per k. w. h. will vary with the back-pressure as under:

Back-Pressure	Pounds Steam per K.W.H.
0	32.34
1	33.00
2	33.66
3	34.33
4	35.00
5	35.70
6	36.40
7	37.12
8	37.84
9	38.60
10	39.35

Such a condition will also require a readjustment of the valve settings on the heaters and evaporators, to be again changed when conditions return to normal, but in the interval dirty juice has entered the evaporators, and light syrup has gone to the pan supply tanks.

It is evident, therefore, that plans for a power salvage installation must go much beyond planning the power house, and that the personnel for its successful operation are not the power house employees only.

A Better Understanding of Pokkah Bong and Twisted Top of Sugar Cane

By H. Atherton Lee

Introduction

In 1898, Wakker and Went* described and illustrated in colors a disease of sugar cane called *pokkah bong.* The words pokkah bong are from the native Javanese dialect and, translated into English, mean twisted top. The disease has been mentioned frequently in the 30 years since that time; it has always seemed rather obscure in nature and but vaguely understood.

The disease is not common in Java at present. It occurs in the Philippines on but one variety, a cane which is used by children for chewing and eating rather than for commercial sugar production; the disease is therefore not of commercial importance in the Philippines. It was first reported from Louisiana on some of the P. O. J. varieties by Dr. E. W. Brandes in a short note in *Facts About Sugar.* Dr. Edgerton has also made mention of the disease in Louisiana on the P. O. J. varieties, in a bulletin from the Louisiana State Experiment Station.

In Hawaii, we have a trouble rather commonly found on the variety H 109 which has been called pokkah bong, twisted top, top knot and various other names.

Most pathologists, among them the writer, seem to have regarded the Java form of pokkah bong as an infectious disease. Dr. Brandes, however, stated that the disease was physiological. On his recent visit to Hawaii, Dr. Went expressed the opinion that the Java pokkah bong was quite distinct from the twisted top in Hawaii. This had been the view held by the writer, although the data presented in this paper have altered this view.

The disease, using the word disease to include any injuries to the cane plant, non-infectious as well as infectious, in Hawaii, on the variety H 109, has the following characters: One notices that some of the tall cane stalks appearing above the usual height of a cane field do not have their leaves expanded normally, but a mass of closely wrapped, twisted ribbons of leaves. Examining more closely one will observe that many of the leaves are split and the growing mass of the cane top is wrapped around by such split leaves. The outermost leaves of the bunched cane top are the usual green color of normal leaves, but the younger inner leaves are of a greenish yellow color. Moreover, these younger inner leaves are not of the usual texture of normal leaves, but are buckled and corrugated and have somewhat the character of crumped cabbage leaves. These inner leaves are very rigid and seem to be under considerable mechanical tension. Canes occurring naturally in the field with such an appearance are shown in Fig. 1.

Less advanced stages of the disease are sometimes seen in which the whole top of the cane is not tied up, but the tips of the leaves as they emerge from the

* Wakker, J. H., and Went, F. A. F. C. De Ziekten van het Suikerriet op Java. E. J. Brill, Leiden, 1898.

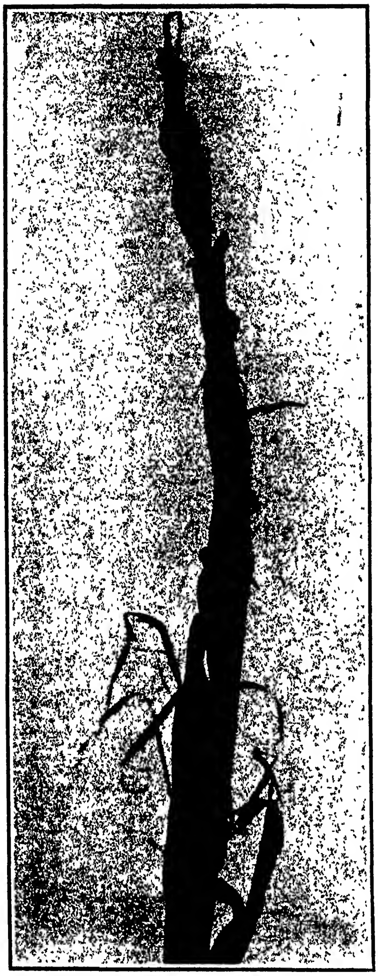


Fig. 1. A naturally occurring case of twisted top in severe form on H 109.

Fig. 2. A mild case of twisted top on H 109 showing arched appearance of leaves; this is also a natural case.

growing point do not separate from each other. Such cases with the lower parts of the leaf blades distended but tied together at their tips have an arched appearance; such a case as it occurred naturally in the field is shown in Fig. 2.

Observations on the Occurence of the Disease in the Hawaiian Islands

The summer of 1926 in the Hawaiian Islands was a period of unusual drought. In the fall of 1926, an unusual occurrence of twisted top occurred at both Ewa Plantation, on Oahu, and Pioneer Mill Company, on Maui. One should note that both of these plantations are on the leeward extremes of the Islands on which they are situated, and both plantations grow H 109 cane under conditions of unusual atmospheric aridity; irrigation in general is by furrow. The disease became so severe in the fall of 1926 that there were a number of cases of top rot observed following the severe tying up of the leaves.

One observation which was recorded was that the disease was of much more common occurrence around the edges than in the middle of the field.

Also it was noted that the large actively growing second shoots or suckers were the stalks usually affected rather than the primary, more slowly growing canes of smaller diameter.

A third observation was that the disease was much less common in experiments where overhead irrigation was being employed than in the fields with the usual furrow irrigation.

With this background of observations many theories were formed and discarded. The theory which has been proven with some success was developed from a remark made by Norman King, agriculturist of the Pioneer Mill Company. Mr. King and the writer were examining affected stalks. It was accepted that the first step in the progress of the disease was the failure of the young emerging leaves to separate at the tips. This was very evidently due to the deep corrugations in the leaf tips which enmeshed the tips of the leaves. Mr. King remarked that it looked to him as if there was some cause of friction as the leaves were emerging from the central cylinder of the cane top, and this friction caused a buckling of the leaf when it was in a young and formative age, which became fixed as the leaf became more mature and hardened.

This view appealed to the writer, for in a previous study of leaf structure, the presence of short rigid hairs or bristles was observed on H 109 leaves, usually at the tips of the leaves and also along the leaf edges. There are two types of hairs on H 109. The hairs of the first type are larger and occur most commonly near the leaf tips. The hairs of the second type were pointed out by D. M. Weller, of this laboratory, and are shorter and more rigid; they are curved upward and occur principally on the lower surfaces of the leaves. A photomicrograph by Mr. Weller of these hairs is shown in Fig. 3. Such hairs would afford a considerable cause of friction of the youngest, most rapidly growing leaves. This friction occasioned by the leaf hairs was visualized as causing a gripping of the youngest leaves against the older leaves causing a cessation of advance until the pressure of growth became so severe as to force a release, when there would be a second gripping and a second release. This alternating gripping and releasing of the leaves when they were in the young, soft, formative stage was visualized as the cause of the fixed corrugations in the leaves when they emerged from the central cylinder.

There were several observations of the occurrence of this trouble which fitted in with this theory. First, the common occurrence of the corrugations at the tips and edges of the leaves, correlated with the position of the longer hairs on the leaves. Secondly, the occurrence of the twisted top most commonly on plantations with an arid atmosphere would mean that there would be less dew on such plantations, and consequently less lubrication for the young, vigorously advancing leaves as they emerged from the central cylinder. The absence of the trouble in cane with overhead irrigation would also correlate with this observation as regards an arid atmosphere.

Thirdly, it has been shown experimentally that when plants of a given species are removed from a humid atmosphere to an arid atmosphere the numbers of

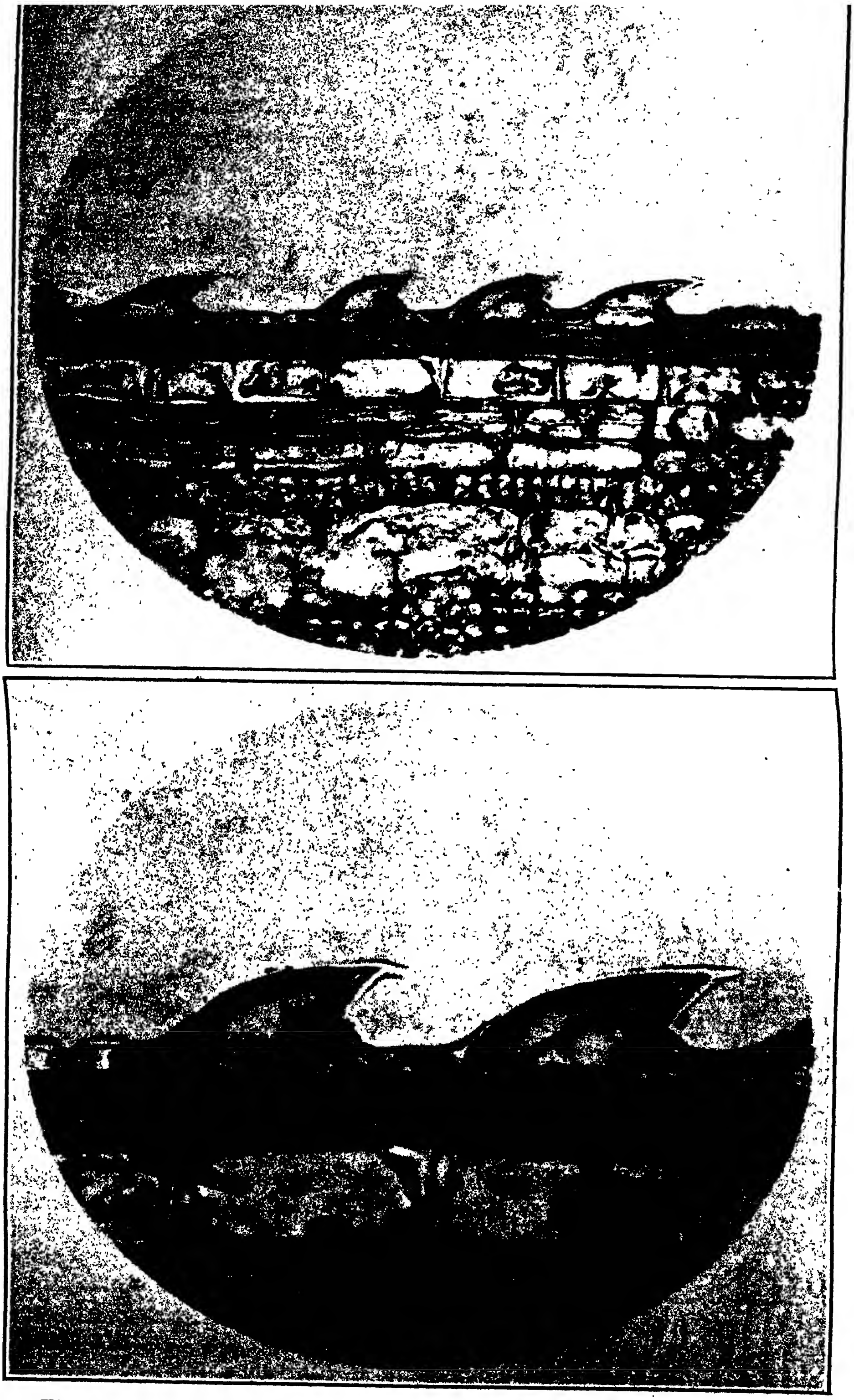


Fig. 3. Photomicrographs by D. M. Weller. The upper figure shows the bristles on the lower surfaces of H 109 leaves magnified X50. The lower photomicrograph shows two of the same hairs magnified X150. These hairs curve upward on the leaves and produce the gripping of the younger leaves against the older leaves as they are pushing out from the central cylinder.

leaf hairs are greatly increased on the leaves which subsequently emerge in the arid atmosphere. Conversely removing plants from an arid atmosphere to a humid atmosphere results in a lessened formation of leaf hairs. A fourth correlation exists in the varieties which are commonly affected with this disease and the abundance of leaf hairs on such varieties. For instance, the varieties H 109 and H 456 are very commonly affected with twisted top and have an abundance of short, bristly leaf hairs at their tips. On the other hand, the production of leaf hairs on such varieties as Yellow Caledonia, Badila and Striped Mexican is considerably less, and on these varieties twisted top is very seldom observed.

The theory at this stage seemed possibly somewhat bizarre, but correlated well with the field observations. What was necessary to establish the theory was an experiment to remove the friction and so bring about a recovery of or avoid the disease; this seemed very difficult, for no way seemed evident to remove the leaf hairs from the young leaves in the central cylinder without destroying the cane top. An alternative suggested itself, to increase the friction on such young leaves while they were still in the central cylinder and thus produce the disease artificially; such an experiment would rather definitely substantiate the theory if the disease was reproduced. This was therefore attempted as follows:

Experiment 1

An attempt was made to reproduce twisted top by increasing the friction of the young, actively advancing leaves as they emerged from the central cylinder.

In this experiment 20 stalks of plant H 109 cane, about six months old, were selected. The central cylinder of young, still unfolded leaves on these 20 stalks, was bound closely, but not too closely, with a six-inch strip of ordinary black friction tape, or bicycle tape, about 1 inch wide. The purpose of this was to create friction between the younger, newly emerging leaves as they advanced upward in the central cylinder, and the other leaves still tightly rolled in the central cylinder of the cane top. Ten of the stalks had the leaves of the central cylinder bound near their tips, while the other ten had the leaves bound near their bases.

The photographs reproduced in Figs. 4 and 5 show the results obtained on the stalks in which the central cylinders of leaves were bound at their bases. There was a fine reproduction of twisted top resulting from this increased friction at the bases of the young leaves. Fig. 4 shows the early stage of development, with the leaves so corrugated that their tips are entangled, presenting an arched appearance as they emerge, and try to separate but are enmeshed at their tips. Fig. 5 shows a later stage of the disease where the next emerging leaves have been obstructed by the arched, entangled leaves, and these new leaves have split through the older leaves; the split older leaves then have a tendency to tie up and increase the friction on the younger leaves, accentuating the twisted top condition.

Of the ten stalks in which the central cylinders of leaves were bound at the bases, all resulted in more or less severe cases of twisted top. Of the stalks on which the central cylinders were bound near the leaf tips, the leaves grew ahead and pushed the tape off in a few days, thus releasing the pressure on the next youngest leaves, with no permanent injury.

Fig. 4. A case of twisted top in the early stages, produced artificially on a stalk of H 109, by increasing the friction on the young, newly emerging leaves. This friction was created by binding the central cylinder of emerging leaves with friction tape; the tape is seen on the older leaves hanging to the right.

Fig. 5. A more advanced case of twisted top produced on a stalk of H 109 by increasing the friction of the young, newly emerging leaves. This friction was created by binding the central cylinder of emerging leaves with friction tape as in the case shown in Fig. 4. The tape is seen on the older leaves hanging to the left.

Experiment 2

The experiment was repeated with 20 stalks, on ten of which the central cylinders were bound with an elastic tire tape and ten with the same friction tape. The central cylinders with the elastic tire tape exerted so much pressure that the tape was broken and no twisted top resulted. The ten central cylinders bound with the friction tape again resulted in typical twisted top, some of them extremely severe. An illustration of two of these cases is shown in Fig. 6.

Fig. 6. Two severe cases of twisted top on stalks of H 109 produced by increasing the friction on the young leaves as they were emerging from the central cylinder.

Arthur F. Bell, of the Queensland Government Bureau of Sugar Experiment Station, saw these results, and it may be of interest to quote from his letter written to the writer concerning the results:

While visiting the pathology plot this morning I was very interested to observe the malformation of the cane tops of H 109 which you have produced by artificially increasing the friction between the growing leaves. The effect produced immediately struck me as being identical with a condition which we have observed in Australia, and which we have somewhat loosely called "Pokkah Bong." From a few rather casual observations it seemed to me that this "Pokkah Bong" was associated with heavy soils where, following a period of dry weather and slow growth, rapid growth was suddenly resumed after a fall of rain.

During this work it was observed that on some of the less hairy varieties, such as D 1135, a few sporadic cases of twisted top would occur throughout a field, showing a difference in character of distribution as compared to the distribution

of twisted top on H 109, the latter type usually occurring only along the edges of fields. This gave rise to a third experiment as follows:

Experiment 3

Twenty cane stalks were selected and marked, but instead of binding with friction tape, the central cylinders of young leaves were bent abruptly about midway in their height. The theory in this was, that such a bend would put pressure on the young, newly formed leaves, causing corrugations of the leaves and ultimate splitting of the older leaves which would cause the typical tying up of twisted top. Such a bending of the central cylinders could easily be occasioned

Fig. 7. A case of twisted top of H 109 produced artificially by simply bending the central cylinder of leaves so as to obstruct the emergence of the still younger leaves within. This obstruction then causes buckling and twisting of such young leaves with the formation of corrugations of the leaves as in the case of the twisted top by increased friction.

by a strong wind, or in young cane by laborers or work animals as they pass down the rows of cane.

This experiment also gave positive results, all of such stalks with abruptly bent central cylinders resulting in twisted top. One of these cases is shown in Fig. 7.

Experiment 4

A fourth experiment was put in at the Pioneer Mill Company, on Maui, using bicycle tape as in Experiment 1 to increase the friction on the young, newly emerging leaves. The results of this experiment may be best presented by quoting from a letter from Mr. King, who cooperated in the experiment:

> In regard to the curly top test at Pioneer, the following are the results:
>
> Visited the test first about a month and a half after starting, and then twice after that. Although but a few marked stalks could be located in the casual observations, I noted that in every case where the tape was successful in maintaining its position about the leaves, curly top was conspicuous. Of the untreated stalks none could be seen that were developing curly top.
>
> Today I made a systematic search for the labeled stalks, and although not able to locate all of them, found 13 of each, making a total of 26. We labeled 20 each, with a total of 40 in the beginning. Three of the stalks marked "Taped" had lost their tape and no curling was evident. The other ten all exhibited curliness, but in varying degrees. Five were quite badly curled.
>
> Of the 13 marked "X" (no tape) only one showed a slight tendency to curl at the tips of the leaves. Two others had been badly lacerated by passing trains and showed no curling. The remaining 7 showed no signs of curling and apparently were growing normally.
>
> On the whole the test points clearly in favor of the theory that the curly top is the result of friction, made more pronounced by rapid growth.

Conclusion

(1) It seems evident that twisted top as it occurs in Hawaii and probably in Louisiana is a mechanical difficulty and is non-infectious.

(2) The writer, at first inclined towards the feeling that the Java and Philippine form of the disease was infectious and distinct from this form common in Hawaii. With the development of this work, however, one begins to feel that the form in Java and the Philippines might simply be a more severe form of this mechanical injury. One would at least feel doubtful in considering any form of this disease as infectious.

(3) The disease in some of the varieties with short, stiff leaf bristles, may result in arid atmospheres from friction of the newly emerging leaves against the more slowly growing older leaves. This friction results in an alternating gripping and release of these young leaves as they advance, causing a buckling of the leaf tissues. Being in a young formative stage, the leaves which are so retarded and buckled show fixed corrugations when they emerge. These corrugations of the newly emerging leaves become enmeshed and prevent the leaves from separating at their tips as they normally would. The enmeshed leaves form arches against which younger, newer leaves are obstructed, and there is then a consequent greater buckling, and splitting of leaves, which results in typical twisted top.

(4) A mechanical injury to the central cylinder of young leaves of the cane top from wind or the field laborer or work animals may also result in twisted top. It is probable that any injury to the central cylinder of leaves of the cane top, which obstructs the free emergence of the younger, inner, actively advancing leaves, will cause a buckling of the leaves and formation of corrugations on the leaves or splitting of the leaves, and ultimately twisted top.

Experiments Showing the Cause of Leaf Burn of Sugar Cane

By H. Atherton Lee

A disease, known variously as leaf burn, wind burn, leaf scorch, tip burn and occasionally by other names, has been definitely recognized in these Islands since 1920. It is probably the same disease which Cobb described in 1908 as tip wither. It is evident that the disease is not new in the Islands.

The disease is most generally noticed in a field when parts of the leaves are killed and browned. Closer observation shows that the younger leaves are most commonly affected. Such affected leaves are killed along the edges, although occasionally a blotch may appear inside the edges of the leaves and not extend to the margin. The killed areas may extend the width of the leaf blade to the midrib or be a very narrow margin along the edge of the leaf. The midrib does not seem to be affected.

Affected leaves are first a dull, dry-green color, much the same color as the normal leaf except that the gloss and sheen of the normal leaf are lost. The affected parts of the leaf shrivel a little. With time, these dry-green areas fade, become ashen, and then tan-colored. When a cane plant has many of such leaves affected it appears to be stunted. The older leaves are not usually affected.

The disease occurs most frequently along the edges of fields, although in young cane it may be found well distributed throughout the inside of a field. The variety U. D. 1 is rather frequently affected. H 109 is sometimes observed affected, but not as frequently as U. D. 1. One case has been observed on D 1135, but the writer has not observed the disease on other varieties although it probably does occur.

Experiments to Show the Cause of the Disease

The word disease is used here to include abnormalities in the cane which are non-infectious, that is, nutritional, mechanical or genetic, as well as those which are infectious.

Cobb ascribed the cause of tip wither to a fungus. The cause has also frequently been ascribed to electrical disturbances in the air, wind injury and drought. The disease has not caused great concern in H 109, but attention has been occa-

sionally called to it and mild concern expressed regarding its spread. With the advent of the variety U. D. 1, which is more commonly affected, there has been more demand to know its cause and methods of avoiding or combating the trouble.

Although the occurrence of the disease in the field was somewhat suggestive of an infectious agent as the cause, the very rapid spread of the killed areas on the leaves was evidence against this view. Usually the disease showed over the entire surfaces of leaf blades in 6 to 8 hours, an advance much more rapid than would be expected of the most virulent pathogenic organisms. The first efforts to find the cause of the trouble were therefore directed towards determining the effect of physical factors on the cane plant.

Without recounting earlier experiments with negative results, the clue was derived from one of these experiments in which leaves of cane plants, softened by an environment of humid, cloudy weather for a number of days, would burn when exposed to one of the brisk northeast tradewinds, common to these Islands. An experiment was therefore set up as follows: Twenty plants of the variety U. D. 1 were grown in concrete pots until 2 months old. They were then fertilized with nitrate of soda and after an interval of 10 days placed in a moisture cage, with high humidity and the sunlight considerably screened. After several days in this environment the plants were removed to a greenhouse with a rather dry air. Ten of the plants were placed upon a table about 10 feet in front of two 15-inch oscillating desk fans; the other 10 plants were placed in the rear of the desk fans, where they were subjected to the same environment, but without being subjected to the breeze of the fans.

The fans were allowed to play on the ten plants from 9:30 a. m. to 5:30 p. m. and then stopped. At the end of that time the youngest leaves of the cane plants in the breeze showed the dry-green color and shriveled edges of typical leaf burn in its early stages. The control plants, not exposed to the breeze, remained entirely normal.

In two days the plants which had been subjected to the breeze for 8 hours showed the younger leaves shriveled, faded, and ash-colored, and in one week such plants had gone through all the typical stages of leaf burn.

At this stage the conclusion seemed to be that leaf burn was really wind burn. However, subsequent experiments slightly modified this view.

The experiment was repeated in order to corroborate these results. In the second experiment the potted plants of the variety U. D. 1 were not fertilized with any nitrogen fertilizers. They were subjected to the same seven days in the moisture cage, with high humidity and sunlight reduced, as in the case of the potted plants in the previous experiment. Ten of these potted plants were placed before two oscillating desk fans and 10 plants were kept protected from the breeze as controls, as in the previous experiment. The fans were allowed to play for the same length of time. After 8 hours of such breeze there were only very slight evidences, if any, of leaf burn on the plants exposed to the fans. The controls remained normal.

The results of this experiment were inconclusive and seemed to fail to corroborate the results of the first experiment. It was suspected, however, that the difference in results was caused by the non-application of nitrogen fertilizers.

A third experiment was therefore carried out. In this case 20 potted plants of the variety U. D. 1 were fertilized with nitrate of soda, and after an interval of a week were placed in moisture cages for 8 days in an environment of high humidity and lessened sunlight. Ten of the plants were then placed on a table before two oscillating desk fans and the remaining 10 plants placed on a second

Fig. 1. At the left four healthy control plants. At the right four plants showing leaf burn produced artificially by increasing transpiration by means of a breeze from oscillating desk fans. All plants are of the variety U. D. 1 and had been treated previously with nitrogen fertilizers and submitted to an atmosphere of high humidity.

Fig. 2. A closer view of the four plants of U. D. 1 with the artificially produced leaf burn, shown in Fig. 1. The ashen-colored leaves and somewhat shriveled edges and tips of the leaves typical of leaf burn are shown.

table, but to the rear of the desk fans. The fans were played on the first 10 plants for 8 hours. The day was unusually dry with a bright, strong sunlight through the clear glass roof of the greenhouse.

At the end of the 8 hours' exposure to the fans the 10 treated plants showed abundant leaf burn. However, some of the 10 control plants without the breeze also showed a slight degree of leaf burn. The results are shown in the photographs reproduced in Figs. 1 and 2.

Fig. 3. At the right, five of the ten fertilized plants with leaf burn resulting from being subjected to the breeze of two oscillating desk fans for eight hours. At the left, five of the ten fertilized plants placed as controls in the rear of the desk fans. All plants are of the variety U. D. 1 and had been treated with nitrogen fertilizers and then subjected to eight days of an environment of high humidity and decreased sunlight.

Fig. 4. At the left, five plants which had received no nitrogen fertilizers, and at the right five plants which had received nitrogen fertilizers. All plants are of the variety U. D. 1 and were subjected to an environment of high humidity and lessened sunlight for eight days and then exposed to the breeze of two ordinary oscillating desk fans for eight hours. As is evidenced in the illustration, the plants with the nitrogen treatment showed abundant leaf burn, while the plants with no nitrogen showed but one mild case of leaf burn.

Fig. 5. The five control plants which had received no nitrogen. They were placed in the rear of the desk fans and shielded from the direct rays of the sun by a screen of thin cheesecloth. These plants all remained normal and showed no symptoms of leaf burn.

The conclusion reached from this experiment was: that leaf burn did not result alone from wind on soft, succulent leaf tissues, but that after an environment of absence of sun and high humidity, plants subjected to excessive transpiration caused by either wind or intense sunlight would result in leaf burn. It also seemed probable that nitrogen fertilizers placed the plants in a condition in which they were more susceptible to leaf burn. These results were not entirely conclusive, however, for we had no controls which had not been subjected to strong sunlight.

A fourth experiment was therefore undertaken as follows: Thirty potted plants of the variety U. D. 1 were grown, of which twenty were treated with nitrate of soda as a source of nitrogen fertilizer. All 30 plants were then placed in the moisture cage where they were submitted to an environment of high humidity and diminished sunlight for 8 days. All 30 plants were then removed to the dry greenhouse. Ten of the 20 plants which had received nitrogen fertilizer, and 5 of 10 plants which had received no nitrogen fertilizer, were placed upon a table in front of the 2 oscillating desk fans. The remaining 10 plants of the 20 which had received nitrogen fertilizer, and the 5 plants with no nitrogen fertilizer, were placed as controls on a table in the rear of the desk fans. These 15 control plants were shielded from the direct rays of the sun by a thin screen of cheesecloth. The fans were then allowed to play on the first 15 plants for 8 hours.

At the end of 8 hours the 10 fertilized plants standing in the breeze showed severe leaf burn in every case. Of the unfertilized 5 plants standing in the breeze 4 showed no leaf burn and the fifth showed but a mild case of leaf burn. These results are shown in Figs. 3 and 4.

Of the 15 controls standing in still air, and protected from above by the cheesecloth screen, one plant at the west end had received the afternoon sun; it showed moderate symptoms of leaf burn. The other control plants all remained normal. These results are shown in the photographs reproduced in Figs. 3, 4 and 5.

The conclusions reached from this last experiment are that:

Leaf burn results from excessive transpiration which may be occasioned by either a steady, constant, brisk breeze or intense sunlight. This leaf burn occurred only on the plants which had recently received nitrogen fertilization. The disease is clearly non-infectious.

Discussion

In view of the fact that excessive transpiration occasioned by sunlight as well as wind, will cause this disease, it is preferable to apply the name of leaf burn, rather than wind burn to this trouble. The action of the wind or sunlight, or possibly the two together in some instances, apparently results in a removal of the moisture from the leaves more rapidly than it can be supplied from the stalk and roots. Nitrogen fertilizers seem to increase this transpiration. The experiments show, that with varieties susceptible to leaf burn, nitrogen fertilizers should be applied with discretion as regards probable weather factors. The injury to the leaf apparently results from a collapse of the cells in the leaf tissues following a too rapid loss of moisture.

Leaf burn in some instances may cause a greater injury than merely a reduction of leaf area. If the transpiration of the leaves is increased gradually, there is a translocation of nutrients by the plant to the leaves, apparently to protect the leaves from excessive transpiration. If, in spite of this, leaf burn results, there is a loss, not only of leaf area, but also a considerable supply of elaborated plant materials as well as inorganic nutrients. This would explain the considerable stunting which has been observed in stools of cane affected with leaf burn. This was first pointed out for wind burn of the foliage of citrus trees by Haas and Reed.*

When the foregoing results were obtained a search of the literature was made to see if there were similar troubles in other crop plants. It was found that leaf burn of sugar cane apparently is not an isolated instance of injury from excessive transpiration. There is a leaf burn of citrus trees in California shown to be caused by excessive transpiration resulting from dry winds. The late Dr. F. C. Newcombe, formerly Professor of Botany, University of Michigan, cited an instance of leaf scorch of maple trees caused by drying winds following warm, humid weather in summer months. A leaf scorch of orchard trees, which would seem to be a somewhat similar trouble, is known in England.

A possible factor in this leaf-burn injury in relation to weather has been brought out in discussion by D. M. Weller, of this laboratory. He points out the research by Priestly, showing that leaves formed in a humid environment have less cuticle than the leaves of an identical plant formed in an arid environment. Thus the susceptibility of cane to leaf burn following 8 or 10 days of kona weather, might in part be explained by the lessened cuticle of the leaves emerging during the kona period.

*** Haas, A. R. C., and Reed, H. S. Relation of desiccating winds to fluctuations in ash content of citrus leaves and phenomenon of mottle leaf. Botanical Gazette, Vol. LXXXIII, No. 2; April, 1927, p. 161.**

Methods to Minimize Leaf Burn

In view of the foregoing results it is possible to mention a few measures which might be undertaken to diminish leaf burn if the injury to the cane warranted attention.

Leaf burn in H 109 and D 1135 is so rare and causes such negligible injury that it probably can be disregarded.

With the promising new variety U. D. 1, in which injury is more common and more severe, the exercise of some discretion in the use of nitrogen fertilizers in relation to the weather probabilities should considerably minimize the trouble. If drying, leaf-burn weather occurs unexpectedly, following a week of kona weather and about two weeks after nitrogen fertilizer applications, an irrigation to increase the atmospheric humidity would have a minimizing effect in decreasing the excessive transpiration.

Although windbreaks are in some cases decidedly disadvantageous, in the case of fields of U. D. 1, they would be advantageous should leaf burn ever become a very considerable factor.

Summary

1. Leaf burn of sugar cane is a non-infectious disease.

2. It is caused by excessive transpiration of the leaves as shown experimentally by subjecting potted cane plants to the breeze of oscillating desk fans, or intense sunlight.

3. Nitrogen fertilizers predispose cane plants to leaf burn.

4. There is a loss resulting from the disease, not only of the leaf area which is killed, but also of a supply of nutrients and elaborated food materials translocated to the leaves which are transpiring heavily. This loss of nutrients probably explains the stunting effect of leaf burn on affected cane plants.

5. Injuries from excessive transpiration similar to leaf burn of sugar cane have also been established on other crop plants.

6. The disease is not infrequent in the variety U. D. 1 and is occasionally found in H 109. It has been observed on D 1135, but has not been observed on the other standard varieties of these Islands.

7. The disease being clearly non-infectious, it seems probable that it can be disregarded on such slightly affected varieties as H 109 and D 1135. Of the variety U. D. 1 some attention to the time of application of nitrogen fertilizers in relation to the probabilities of weather conditions may aid in avoiding the trouble. In periods of drying winds irrigation to increase the atmospheric humidity would be a measure to minimize the injury slightly. Windbreaks would also have a value in this instance.

Oliver Filter Operation for 1927

By H. F. Bomonti

The data contained in this report were taken from the laboratory and boiling house records. It is with the consent of E. W. Greene, Manager; C. J. Fleener and H. W. Robbins, of the Oahu Sugar Company, Limited, that they are presented in this report.

The Oliver filter was put in operation December 4, 1926, and was used throughout the entire grinding season ending July 16, 1927. Stoppages occurred for the following reasons only: washing of filter cloth, changing the cloth, repairing the filter drum, and when the mill was shut down. So far as the writer is aware, at no time did the filter fail to function properly due to poor filtering settlings. At all times, this filter was considered an integral part of the filter station.

Before taking up the performance record of the Oliver filter, it seems more appropriate to discuss the changes and improvements that were either made or contemplated this year.

Two minor changes were made during the year. First, the spray nozzles were mounted in brass pipes throughout the entire system. This was done to eliminate the scale deposits, due to iron pipes, which had a tendency to plug up the very fine perforations in the spray nozzles. Second, the scraper, which is used to discharge the cake from the cloth, was lowered about 10 inches. Lowering the scraper would increase the time interval by 20 seconds after the cake had passed under the last row of spray nozzles and until it was discharged. Increasing the cycle at this phase of the operation would tend to produce a cake of slightly lower moisture content and also lower in polarization.

Two minor refinements were added to the Oliver filter installation during the year. The filter was closed in with a hood. While this was only a temporary arrangement, it is understood that the new filters will be equipped with hoods of a permanent nature. With the filter covered, the fine spray from the spray nozzles is prevented from escaping into the atmosphere. This results in a more efficient use of the wash water. The cake also is kept hotter, which seems to make it more porous. The second refinement made during the year was the installation of an automatic feed valve. With this automatic feed valve in the line, a uniform level of settlings was maintained in the filter. While a constant level could be maintained with an adjustable overflow, it is both undesirable and uneconomical to use such a device.

For the coming year, the filter will be equipped with a new drum. This drum is made of wood, with brass piping and copper screens. It was found that the present drum which was of iron construction failed to withstand the existing conditions. The pipes and inner surfaces of the drum corroded, with the result that rather large holes developed. Such a condition has a very serious effect on the economical operation of the filter. When such leaks develop, the formation of the cake is affected as well as the sweetening-off of the cake.

The data have been arranged in two tables. The form of these tables is about the same as that used in Table XXI of "The Report on the Treatment of Settlings and the Oliver Filter," *The Hawaiian Planters' Record,* Volume XXXI, January, 1927.

Table I gives the average figures of capacities per day and per hour for periods varying from four to five weeks and also the averages for the entire crop.

Discussion of Data

Item 4. Settlings % mixed juice. This figure runs quite uniform for the different months. The minimum, 15.1, is secured in March, and the maximum, 20.2, in July. A spread of only 5.1 per cent between the minimum and maximum is very small.

Item 7. Tons settlings filtered by the Oliver filter per hour. During the first two months the lowest capacities were secured. These were 6.4 and 6.3 tons settlings filtered by the Oliver per hour. The capacity showed a small increase during the months of February, March, and April. In May, June and July there was a marked increase in capacity over the previous months. These variations in capacity are undoubtedly due to the change in composition of the cake solids. During the first few months, winter months, there is apt to be less fiber in the suspended solids. While in the latter part of the season the fiber would tend to increase. It has been quite definitely established that as the percentage fiber in the cake increases, greater capacities are secured.

Item 8. Cake solids discharged by the Oliver per hour. This is a figure which can be used in making comparisons of capacities. The pounds cake solids discharged per hour show a somewhat greater spread between the maximum and minimum than comparison of tons settlings per hour. Comparison of tons settlings per hour shows a spread of 30 per cent between maximum and minimum, while the pounds cake solids discharged per hour shows a spread of over 50 per cent. The variations follow fairly close to those mentioned in Item 7.

Item 10. Tons cane equivalent to tons settlings filtered by the Oliver per hour. This figure is influenced by the volume of settlings % mixed juice. But where the variation in the settlings % mixed juice is small, the figure has some real significance. It is doubtful whether such a figure could be used to compare the performance of a continuous filter in different factories. The minimum 29.9 tons cane equivalent to tons settlings filtered by the Oliver per hour was secured in February. The maximum, 39.1, was secured in May.

Item 13. Settlings filtered by the Oliver % total settlings. During December and January, the filter averaged 23.9 and 22.4 per cent of the total settlings. The averages for the other months were considerably higher. The maximum was secured in April when 30.4 per cent of the total settlings were filtered.

Item 19. Polarization % Oliver cake. The high polarization in the Oliver cake during December, January and February, is due to several factors. The spray nozzles were plugged quite frequently by scale from the iron pipes, causing irregular washing. The cake was not as porous during these months as later in the year. The flow meter used to measure the wash water was out of order. All these factors tended to produce a high polarization. The polarization of the cake was also high in May. This, the writer believes, was due to mechanical defects in the drum.

It seems doubtful to the writer if the average can ever be maintained below 1 per cent for an entire season. With very great care and constant supervision it can be reduced to well below 1 per cent, but with the type of labor available for this work, this does not seem possible.

For a two-week interval in July, the polarization was 0.71; for June it was 0.92; this was considered very good. The average, 1.19, is slightly higher than the average for the two months run last year.

Item 21. Ratio: Polarization % cake solids. The polarization % cake solids is really the figure which should be used to compare the relative efficiency of press work. In the Oliver cake, the moisture is high compared to press cake, so that calculating results in terms of polarization % cake solids makes them comparative. The average for the crop is 7.18, that is the polarization % cake solids. This would be equivalent to 2.0 per cent polarization in press cake having a moisture content of about 70 per cent.

Table II is a comparison between the averages for the year 1927, and for the two months run during 1926. It is evident from Table I that during the months of May and June, the settlings possess better filtering characteristics than during the winter months. For this reason the averages are not strictly comparative, nevertheless they are interesting.

TABLE II

Performance Record of the Oliver Filter	189 Days 1927	50 Days 1926
Tons cane per day	2792	2852
Tons sugar per day	338	380
Tons settlings per day	556	658
Settlings % mixed juice	17.1	20.6
Tons cane per ton of settlings	5.02	4.33
Tons settlings filtered by the Oliver per day	149.1	161.8
Tons settlings filtered by the Oliver per hour	7.10	7.52
Tons cane equivalent to tons settlings filtered by the Oliver filter		
per day	748	700
per hour	35.6	32.56
Hours filtering per day	21.0	21.5
Gallons of settlings filtered per square foot per hour	5.3	5.8
Settlings filtered by the Oliver % total settlings	26.96	24.80
Per cent suspended solids in settlings	3.1	2.28
Thickness of Oliver cake, inches (calculated)	9/32"	7/32"
Tons of Oliver cake per day (calculated)	28.0	23.35
Tons of Oliver cake per hour (calculated)	1.35	1.09
Tons Oliver cake equivalent to ton press cake	1.36	1.40
Polarization % Oliver cake	1.19	1.14
Moisture % Oliver cake	82.24	83.29
Ratio: Pol. % cake solids	7.18	7.42
Polarization % press cake	3.81	4.69
Moisture % press cake	73.45	73.31
Ratio: Pol. % cake solids	16.76	22.24
Estimated saving in tons polarization when all the settlings are filtered with Olivers, per day	1.72	2.01
Tons polarization available from above item	1.55	1.81
Value of sugar saved per ton of sugar manufactured	$0.40	$0.37

Market value of sugar for 1927....$86.00

Market value of sugar for 1926....$74.60

The Purity of the Oliver Filtrate

Routine laboratory samples of the Oliver filtrate were taken over a period of six weeks. These samples represent the total filtrate including the washings. The average purity of the Oliver filtrate and also the average purity of the clarified juice is tabulated below.

	Clarified Juice	Oliver Filtrate	
Brix	13.92	11.90	
Polarization	11.78	9.98	
Purity	84.63	83.87	Difference 0.76

Experimental data secured last year indicated that the difference between the purity of the Clarified Juice and the Oliver Filtrate, including the washings, was about 0.61. The data in the above tabulation show a difference of 0.76 in purity. The writer believes that this agreement between experimental data and factory data is as close as can be expected. Had all the settlings been handled in this way, the above decrease in purity would have depressed the purity of the evaporator supply approximately .15 below the purity of the settled juice. This depression of the purity of the evaporator supply juice is considerably less than is secured under the old system of filtration.

The Yield Equation and Its Application to Sugar Cane Agriculture*

By J. A. Verret and Y. Kutsunai

When the harvesting results of a test on the varying amounts of fertilizer are plotted on a sheet of cross-section paper, with the amounts of fertilizer along the x-axis, the corresponding cane yields along the y-axis, and the resulting points connected by a smooth line, an ascending curve will be formed. It is steeper at the lower amounts of fertilizer than at the higher amounts; in other words, the curve flattens out as the amount of fertilizer increases. The curve shown in Fig. 1 is drawn from actual experimental data.

Such a curve shows at a glance the relation between the varying amounts of the fertilizer and the corresponding cane tonnage not only at the point tested but also at intervening points, and reveals, roughly, where to stop fertilization in order to produce the greatest profit.

A more accurate method of arriving at these critical results is by the use of a yield equation. This will furnish definite information on such important matters as:

1. The maximum amount of fertilizer that can be applied without loss;
2. The amount of fertilizer to use to obtain the highest profit per acre;

*The mathematical work in this paper is entirely by Y. Kutsunai.

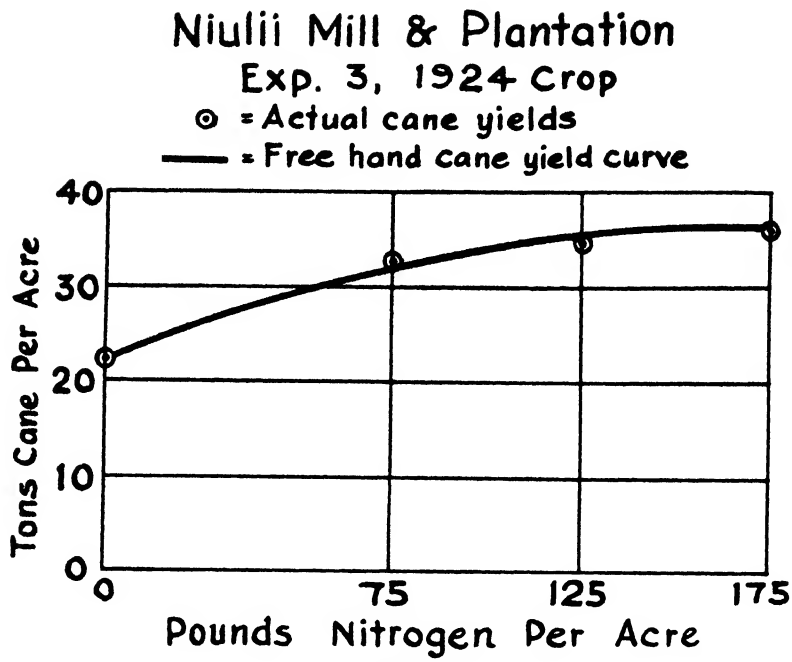


Fig. 1

3. The amount of fertilizer to apply to produce the maximum gain for each dollar invested in the crop;
4. Probable fertility of the field expressed in terms of the fertilizer tested on that field;
5. Accurate determination of the effect of the increase or decrease of a small amount of fertilizer from the standard practice;
6. The comparative efficiency of various forms of fertilizing elements;
7. Determination of the amount of fertilizer that maintains the soil fertility; and
8. The comparative efficiency of different varieties of sugar cane.

Aside from the economic questions that can be answered by means of the yield equation, there are matters of scientific interest capable of solution by the use of this same equation. The latter may include the detection of the limiting factors of growth, establishment of growth factor for the diverse fertilizing elements, and the study of the inhibiting effect of certain soil constituents. However, the present paper is limited to the application of the equation to the economic problems.

Among the many possible mathematical formulae that can be used to express the relation of the yield to the amount of fertilizer, three may be considered important, namely:

Maskell's equation, $Y = \dfrac{1}{k_1 + \dfrac{k_2}{p + P}}$;

Mitscherlich's equation, $\log (A - Y) = \log (A - a)\ kx$;

Spillman's equation, $Y = M - AR^x$.

Of these, Spillman's equation seemed the easiest to understand and to handle, consequently the other two were not followed in detail. The equation, $Y = M - AR^x$, is based on the law of diminishing increments, the truth of which appears to be substantiated by many fertilizer tests. Local fertilizer experiments are cited, for example, of the practical demonstration of the law of diminishing increments.

Makee Sugar Company, Experiment 23, 1927 crop, tested varying amounts of phosphoric acid. The data obtained are:

Pounds Phosphoric Acid per Acre	Tons Cane per Acre	Tons Cane Gained for Each Additional 32 lbs. P_2O_5
144	35.7	...
176	48.7	13.0
208	50.3	1.6
240	50.6	0.3

In this example, the increments in cane yields decrease as the phosphoric acid is increased and the decrease of the successive increments takes place in fairly constant ratios, which are 1 : 0.12 and 1 : 0.19. The slight disagreement in the ratios is well within the experimental error since such fluctuation is caused by an error of only 1/10 ton in the third increment.

Pioneer Mill Company, Experiment 23, 1927 crop, is a test on the amount of nitrogen to apply. The harvesting results are:

Pounds Nitrogen per Acre	Tons Cane per Acre	Tons Cane Gained for Each Additional 50 lbs. N.
140	57.5	...
190	67.6	10.1
240	74.2	6.6
290	78.2	4.0

Here again, the increments in cane are decreasing as the amount of nitrogen increases. The ratios of decrease in the successive increments are 1 : 0.65 and 1 : 0.61, which figures are sufficiently close to be considered constant.

The yield equation of Spillman is based on the law of diminishing increments, a law which is founded on the assumption that increasing amounts of fertilizer or water increase the crop, but the successive increments in crop for each additional lot of fertilizer or water are decreasing at a constant ratio. It is interesting at this point to note that the ratios computed closely approximated the actual figures obtained experimentally.

Plantation Experiments		Actual Ratios	Computed Ratio
Makee Sugar Company.......	23	0.12 and 0.19	0.1519
Pioneer Mill Company........	23	0.65 and 0.61	0.6293

The yield equation of Mitscherlich, although originally founded on other assumptions, can be deduced from this same law.

The harvesting data used in evaluating the terms in the yield equation must, of course, be fairly free of experimental errors, since the equation does not correct errors in the basic data.

In discussing the many uses of the equation, cane tonnage only is considered because the effect of various fertilizers on the quality ratio is not sufficiently well understood to permit the reduction of cane yields to sugar yields with mathematical exactness.

A comparison of the actual harvesting data of Kaiwiki Sugar Company, Experiment 2, 1924 crop, with the calculated cane yields shows a satisfactory agreement.

No. of Lots of Fertilizer	Actual Tons Cane per Acre	Calculated Tons Cane per Acre	Difference Tons Cane per Acre
1	41.6	41.6	0
2	43.6	43.5	—0.1
3	45.0	45.1	+0.1
4	46.6	46.6	0

The calculated cane yields were obtained from the equation, $Y = 59.08 - 19.517 (0.8944)^x$. Each lot of fertilizer was composed of 50 pounds nitrogen and 12½ pounds each of phosphoric acid and potash. Fig. 2 shows the graph.

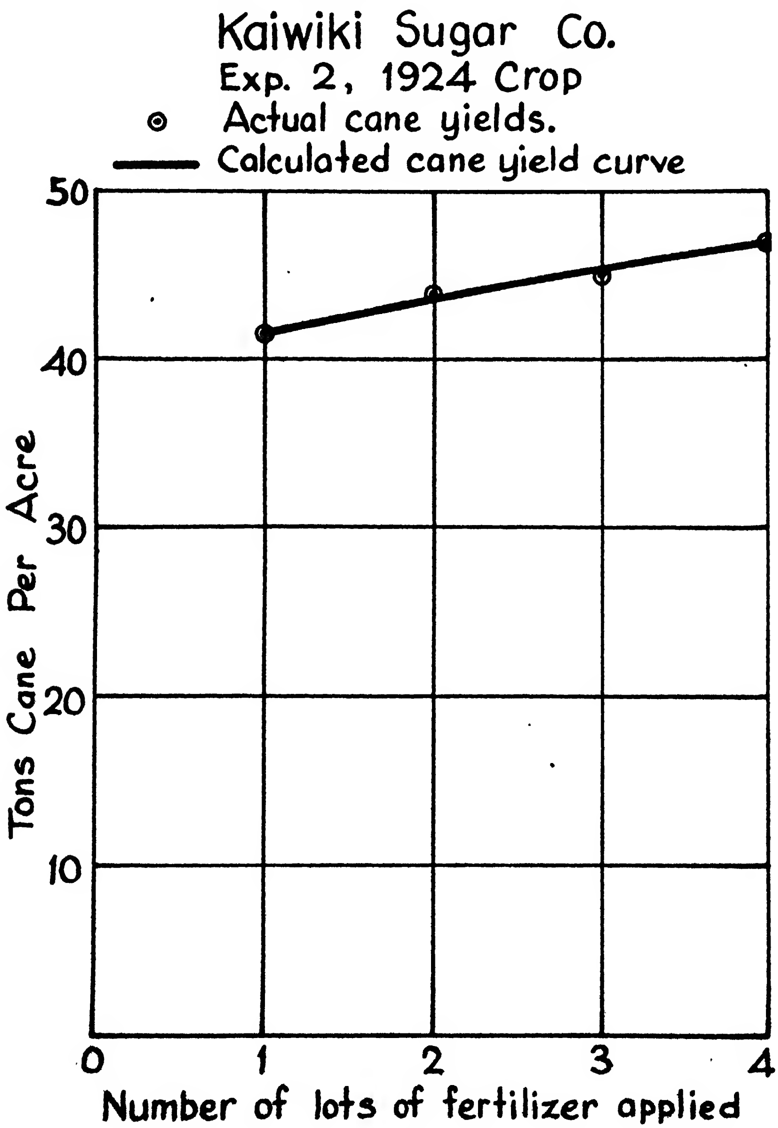


Fig. 2

Another example from Lihue Plantation Company, Experiment 5, 1924 crop, shows the same agreement between theoretical and experimental figures.

Pounds Nitrogen per Acre	Actual Tons Cane per Acre	Calculated Tons Cane per Acre	Difference Tons Cane per Acre
0	27.31	27.29	—0.02
75	39.77	39.86	+0.09
150	47.88	47.81	—0.07
225	52.89	52.89	0.00

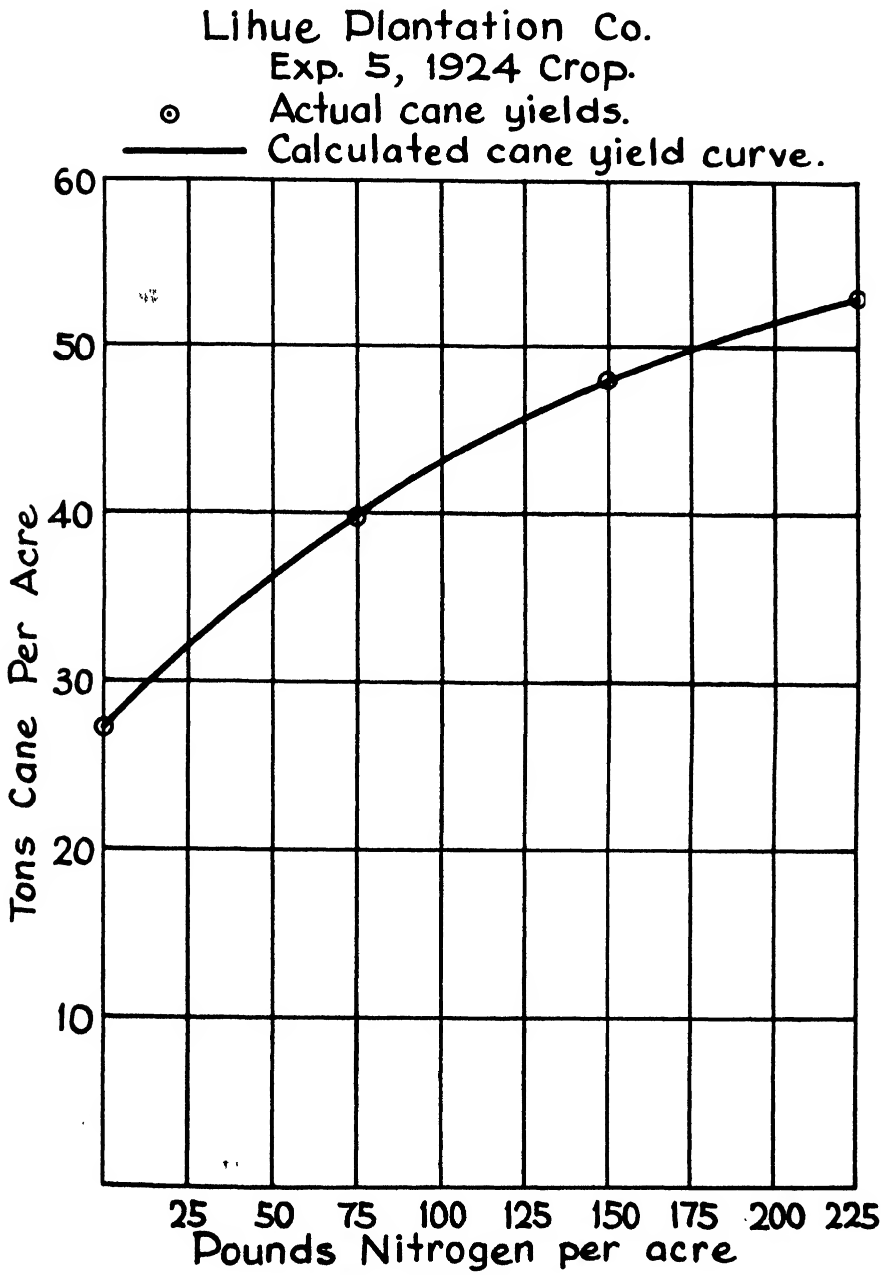


Fig. 3

The yield equation which supplied the calculated cane tonnage is $Y = 61.645 - 34.351\ (0.6341)^x$. Besides the varying amounts of nitrogen, all the plots received 500 pounds of reverted phosphate per acre and a uniform application of molasses ash. Fig. 3 presents the figures graphically.

As the theory of the law of diminishing increments implies, the efficiency of the fertilizing elements declines as the amount of fertilizer applied increases. This tendency is very pronounced in the case of phosphoric acid and potash and less so for nitrogen, and there must be a point beyond which any further increase in fertilization no longer pays. This point may be termed the maximum economical fertilization point at which the cost of additional fertilizer applied to the field is exactly equal to the value of the increase in the crop. Below this the investment in fertilizer brings in profit and above it, a loss. If Q tons of standing cane has the value equal to the cost of one lot of fertilizer applied, the maximum economical fertilization point is obtained by the formula

$$\frac{\log Q - \log\ (-2.302585\, A \log R)}{\log R}$$

The formula expresses the total amount of fertilizer up to the maximum economical fertilization point in number of lots of fertilizer. The weight of the fertilizer is, therefore, equal to the number of pounds in the lot multiplied by the number of lots of the fertilizer.

A numerical example may clarify this explanation. If one lot of nitrogen applied to the field costs \$18 and the value of a ton of standing cane be \$2.50, the amount of cane needed to balance the cost of one lot of nitrogen is $18 \div 2.50 = 7.2$ tons. Using the values A and R in the yield equation, $Y = 61.645 - 34.351\ (0.6341)^x$, of Lihue Plantation Company, Experiment 5, 1924 crop, as cited previously, the maximum economical fertilization point is

$$\frac{\log 7.2 - \log\ (-2.302585 \times 34.351 \log 0.6341)}{\log 0.6341}$$
$$= 6.759.$$

Each lot in this experiment was 75 pounds of nitrogen, hence the maximum amount of nitrogen that can be applied without a loss is 75×6.759 or 507 pounds. This amount is not to be used in practice, however, because costs other than the actual purchase price of the fertilizer cannot be disregarded, and what is desired is not the highest tonnage of cane but greatest profit per acre or per dollar invested.

To secure the maximum profit per acre is the aim of the sugar cane agriculturists of Hawaii. The mathematical analysis of costs and profits based on the yield equation aids in attaining this goal. The profit per acre is the value of cane per acre less the total cost per acre, and it is very simple to find under what conditions the profit is greatest.

The total cost of one acre of cane delivered at the mill may be divided into four general classes, namely:

\$$D$ = cost of a lot of fertilizer which affects the yield of cane according to the law of diminishing increments;

\$$F$ = the fixed charge per acre, such as the rent of land;

$\$T$ = charges per ton of cane that vary directly with the tonnage per acre, for instance, the prices paid to the cultivation contractors, the harvesting cost, including transportation charges;

$\$W$ = charges per acre that vary inversely with the tonnage of the crop, such as the cost of weeding.

The cost of irrigation may be classed under D or T, unless the relation of irrigation and the resulting crop be definitely known. The overhead charge may be added to either F or T. The cost of preparing and planting when pro rated to the various crops according to the crop lengths may be handled as the overhead charge. The relation of weeding cost to the tonnage of cane per acre is not yet clearly known, but for the purpose of illustration may be calculated on the assumption that an acre of bare ground would cost $\$G$ to keep weeds down for one crop length, and that cane grown on the area would save the weeding cost at the rate of $\$H$ per ton cane. When $\$G$ is \$30 and $\$H$ is \$0.25, the weeding cost runs as in the following table:

Tons Cane per Acre	Weeding Cost Per Acre per Crop
10	\$27.50
20	25.00
30	22.50
40	20.00
50	17.50
60	15.00
70	12.50
80	10.00
90	7.50
100	5.00
110	2.50
120	0.00

These values were obtained from $\$G - \$H \times$ tonnage.

If X lots of fertilizer or water, the cost of which is classed under D, results in Y tons of cane per acre, then the total cost of a crop of Y tons per acre is

$$\$DX + \$F + \$TY + \$G - \$HY.$$

Now, if the value of one ton of cane at the mill be $\$V$, then the total value of cane from one acre is $\$VY$. The profit per acre is the value less the cost, or

$$\$VY - (\$DX + \$F + \$TY + \$G - \$HY).$$

This profit is the maximum when X is equal to

$$\frac{1}{\log R} \times \log\left(\frac{-D}{2.302585\,(V + H - T)\,A \log R}\right)$$

in which the numerical values of A and R are to be obtained from the yield equation based on the actual experiments on the area. It is noticeable that $\$F$, the fixed charges, and $\$G$, another fixed charge, have disappeared from the formula. The disappearance has some significance in that the so-called point of maximum profit per acre may be the point of least loss under some conditions.

A numerical example is worked to test the validity of the formula. The field is the one in which Lihue Plantation Company, Experiment 5, 1924 crop, was formerly, and the cultural conditions are supposed to be the same as at the time of the experiment. The yield equation obtained is $Y = 61.645 - 34.351 (0.6341)^x$ in which $A = 34.351$ and $R = 0.6341$. Other values assigned are:

$\$D = \$18$ per lot of fertilizers;
$\$F = \$40$ an acre;
$\$T = \$1.50$ per ton cane;
$\$G = \$30$ per acre
$\$H = \$0.25$ per ton cane;
$\$V = \$4$ per ton cane;
$X =$ number of lots of fertilizer of 75 pounds of nitrogen each.

The above figures are not intended to represent actual conditions; they are taken to illustrate the application of the formula.

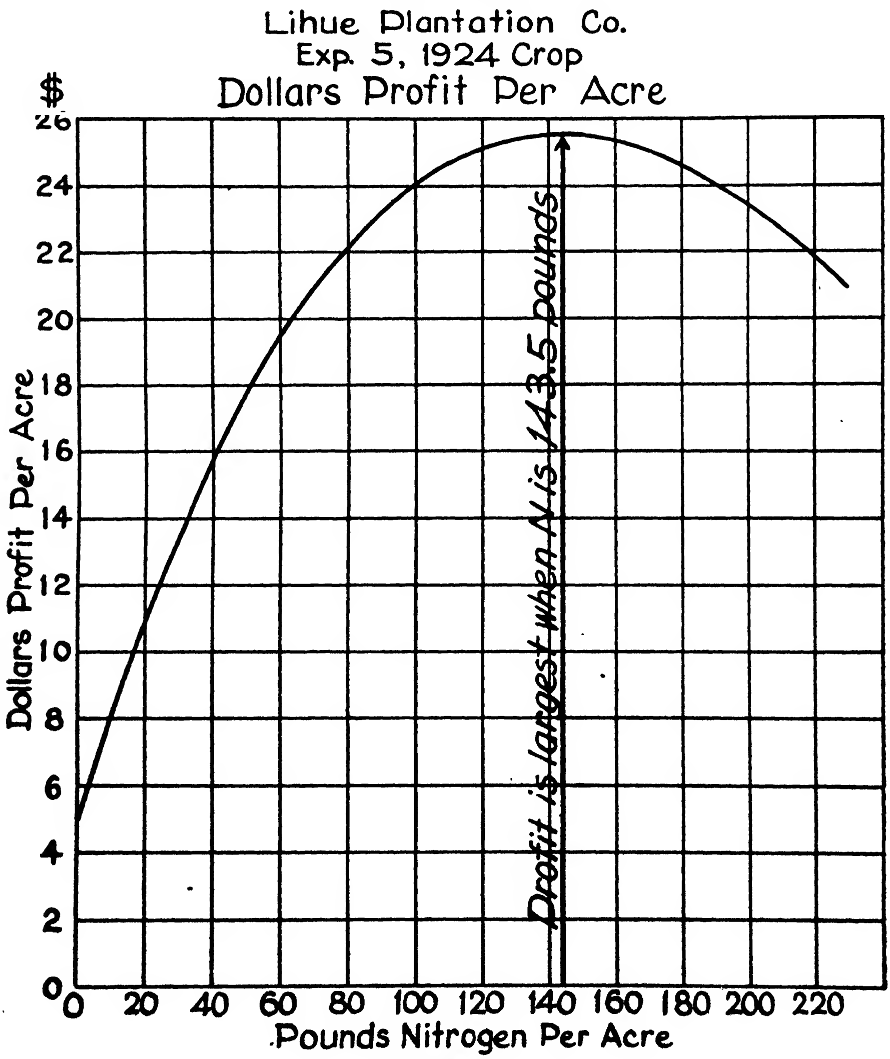


Fig. 4

By substituting these values in the formula and by carrying out the arithmetical operations, indicated, the answer is found in number of lots of fertilizer necessary to secure the maximum profit per acre.

$$X = \frac{1}{\log 0.6341} \times \log \left(\frac{-18}{2.302585\ (4 + 0.25 - 1.50)\ 34.351 \log 0.6341} \right)$$

$$= \frac{\log 0.41827}{\log 0.6341}$$

$$= 1.9134 \text{ lots.}$$

Since each lot is known to be 75 pounds nitrogen, the total amount of nitrogen to apply is 75 x 1.9134 or 143.5 pounds per acre. That 144 pounds is the best amount of nitrogen to use when the maximum profit per acre is sought is brought out in Fig. 4, and also in the following table.

The above amount of 144 pounds of nitrogen would not apply to Lihue at the present time. The experiment was with Caledonia cane, not now planted. With present varieties this figure would be higher.

Pounds Nitrogen per Acre	Tons Cane per Acre	Gross Income per Acre	Cost of Nitrogen per Acre	Fixed Charge per Acre	Tonnage Cost per Acre	Weeding Cost per Acre	Total Cost per Acre	Profit per Acre
X	Y	$\$PY$	$\$DX$	$\$F$	$\$TY$	$\$G—\$HY$		
0	27.278	$109.112	$ 0	$40	$40.917	$23.180	$104.097	$ 5.015
10	39.302	117.208	2.40	40	43.953	22.674	109.027	8.181
20	31.207	124.828	4.80	40	46.811	22.198	113.809	11.019
30	33.000	132.000	7.20	40	49.500	21.750	118.450	13.550
40	34.688	138.752	9.60	40	52.032	21.328	122.960	15.792
50	36.276	145.104	12.00	40	54.414	20.931	127.345	17.759
60	37.770	151.080	14.40	40	56.655	20.557	131.612	19.468
70	39.171	156.684	16.80	40	58.757	20.207	135.764	20.920
80	40.499	161.996	19.20	40	60.749	19.875	139.824	22.172
90	41.744	166.976	21.60	40	62.616	19.564	143.780	23.196
100	42.916	171.664	24.00	40	64.374	19.271	147.645	24.019
110	44.019	176.076	26.40	40	66.029	18.995	151.424	24.652
120	45.057	180.228	28.80	40	67.586	18.736	155.122	25.106
130	46.034	184.136	31.20	40	69.051	18.491	158.742	25.394
140	46.953	187.812	33.60	40	70.430	18.262	162.292	25.520
			Point of Highest Profit Occurs Here					
150	47.818	191.272	36.00	40	71.727	18.045	165.772	25.500
160	48.632	194.528	38.40	40	72.948	17.842	169.190	25.338
170	49.398	197.592	40.80	40	74.097	17.650	172.547	25.045
180	50.119	200.476	43.20	40	75.179	17.470	175.849	24.627
190	50.797	203.188	45.60	40	76.196	17.301	179.097	24.091
200	51.435	205.740	48.00	40	77.153	17.141	182.294	23.446
210	52.036	208.144	50.40	40	78.054	16.991	185.445	22.699
220	52.602	210.408	52.80	40	78.903	16.849	188.552	21.856
230	53.134	212.536	55.20	40	79.701	16.716	191.617	20.919

It is to be noted that the maximum profit is between 140 and 150 pounds of nitrogen and is nearer 140 pounds. The formula gives it to be 143.5 pounds. It pays to borrow money from a bank if the working capital be insufficient to handle each acre to its point of maximum profit, provided the rate of interest be lower than the profit for the duration of the crop.

When, however, it so happens that the working capital is limited, then it behooves the one in charge of the plantation to seek the greatest profit for each dollar invested in the crop. The process of arriving at this point is simple. The formulae used are:

$$\text{Let } L = \left(F + G - \frac{D}{2.302585 \log R}\right)\frac{2.302585\, A \log R}{-DM} + \left(\frac{2.302585\, A \log R}{-M}\right) X$$

$$\text{and} \quad U = \left(\frac{1}{R}\right)^{x}.$$

The meaning of F, G, D, R, A and X are the same as used in the foregoing examples. M is the first number after the equality sign in yield equation, $Y = M - AR^{x}$. The yield equation of Lihue Plantation Company, Experiment 5, 1924 crop, is $Y = 61.645 - 34{,}351\ (0.6341)^{x}$ as was given previously, hence, $M = 61.645$. Inserting the proper values for the terms in the formula, the following results:

$$L = \left(40 + 30 - \frac{18}{2.302585 \log 0.6341}\right)\left(\frac{2.302585 \times 34.351 \log 0.6341}{-18 \times 61.645}\right) +$$

$$\left(\frac{2.302585 \times 34.351 \log 0.6341}{-61.645}\right) X$$

$$= 1.544852 + 0.2539185X.$$

This is a straight line and two points only are needed to determine the line.

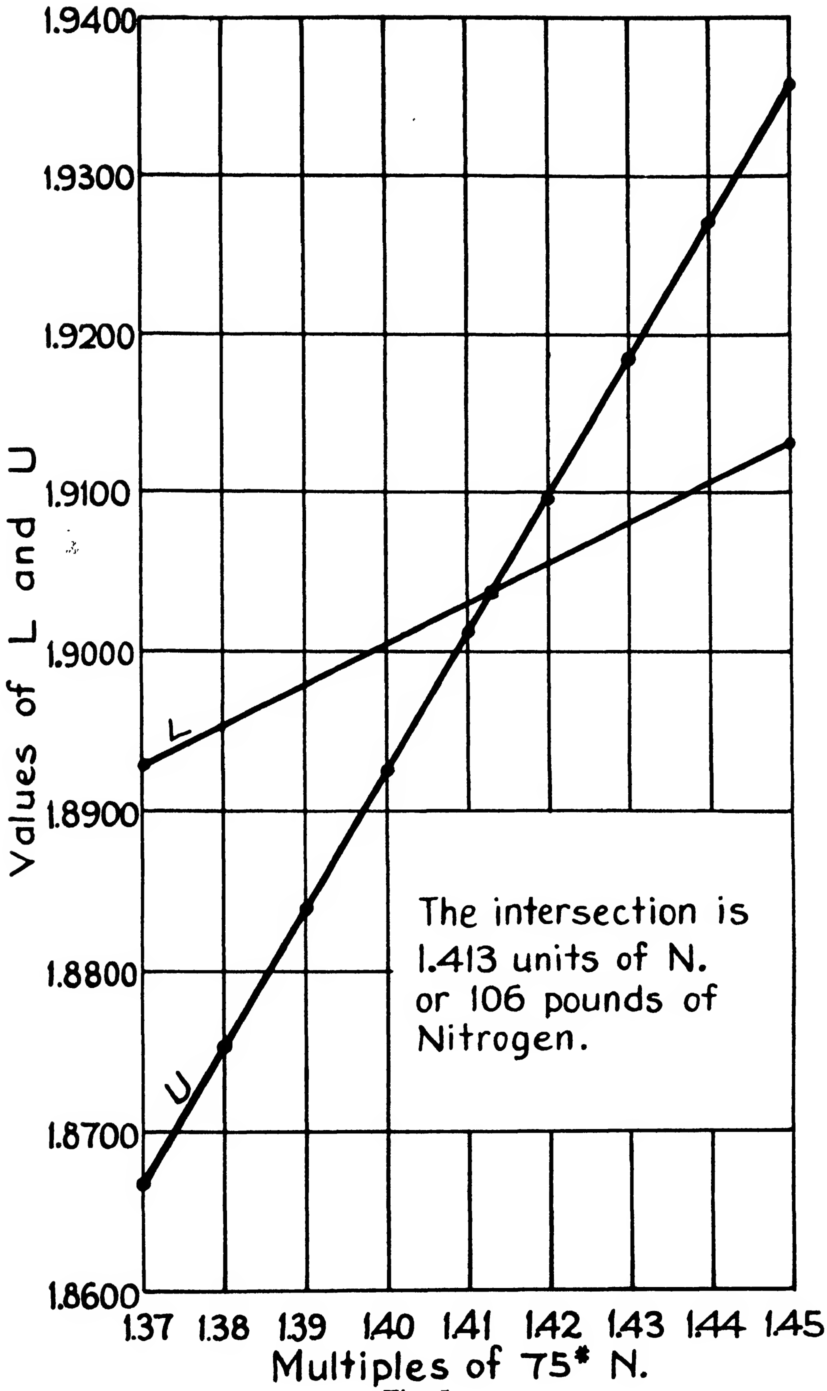
$$U = \left(\frac{1}{R}\right)^{x}$$

$$= 1.57704^{x},$$

which is a curved line, hence many points must be worked out to obtain accuracy.

The values of X tried	L	U
1.37	1.8927	1.8666
1.38	.....	1.8751
1.39	.....	1.8837
1.40	.....	1.8922
1.41	.....	1.9009
1.42	.....	1.9096
1.43	.....	1.9183
1.44	.....	1.9270
1.45	1.9130	1.9358

These values are plotted on cross-section paper, the lines L and U intersect at $X = 1.413$, which shows that the maximum profit per dollar invested in the crop is obtained when 1.413 lots of fertilizer, or in this case $75 \times 1.413 = 106$ pounds of nitrogen, are used. Fig. 5 presents the method of plotting. The following table bears this out. The figures are taken from the previous table.



1.9400
1.9300
1.9200
1.9100
1.9000
1.8900
1.8800
1.8700
1.8600
Values of L and U
L
U
The intersection is
1.413 units of N.
or 106 pounds of
Nitrogen.
1.37
1.38
1.39
1.40
1.41
1.42
1.43
1.44
1.45
Multiples of 75* N.

Fig. 5

Pounds N per acre	Profit per acre	Total Cost per acre	% Profit on cost
0	$ 5.015	$104.097	4.818
10	8.181	109.027	7.505
20	11.019	113.809	9.682
30	13.550	118.450	11.439
40	15.792	122.960	12.843
50	17.759	127.345	13.946
60	19.468	131.612	14.792
70	20.920	135.764	15.409
80	22.172	139.824	15.857
90	23.196	143.780	16.133
100	24.019	147.645	16.268
	Point of Highest Profit Occurs Here		
110	24.652	151.424	16.280
120	25.106	155.122	16.185
130	25.394	158.742	15.997
140	25.520	162.292	15.725
150	25.500	165.772	15.383
160	25.338	169.190	14.976
170	25.045	172.547	14.515
180	24.627	175.849	14.005
190	24.091	179.097	13.451
200	23.446	182.294	12.862
210	22.699	185.445	12.240
220	21.856	188.552	11.591
230	20.919	191.617	10.917

The greatest profit is between 100 and 110 and is nearer 110. This checks the results obtained by the formulae. Fig. 6 is the graph of the table.

It is interesting to compare the three points determined from the same data in connection with the amount of nitrogen to apply.

Nature of the Maximum	Pounds N per Acre
Maximum limit of fertilization........................	507
Profit per acre	144
Profit per dollar invested	106

The comparison clearly demonstrates the necessity of defining the meaning of profitable fertilization prior to computing the amount of fertilizer to use. It may even be necessary to charge the milling expenses to the field because the milling expense per ton cane varies somewhat inversely with the amount of cane handled each year.

The yield equation based on the data of one crop is not entirely satisfactory. The field receiving a fertilization heavier than the amount extracted by the crop, will accumulate plant food, especially phosphoric acid and potash, for succeeding crops. On the other hand, the fields fertilized lighter than the amount drawn away, become poorer from crop to crop. This tendency is readily seen in the results of these two experiments:

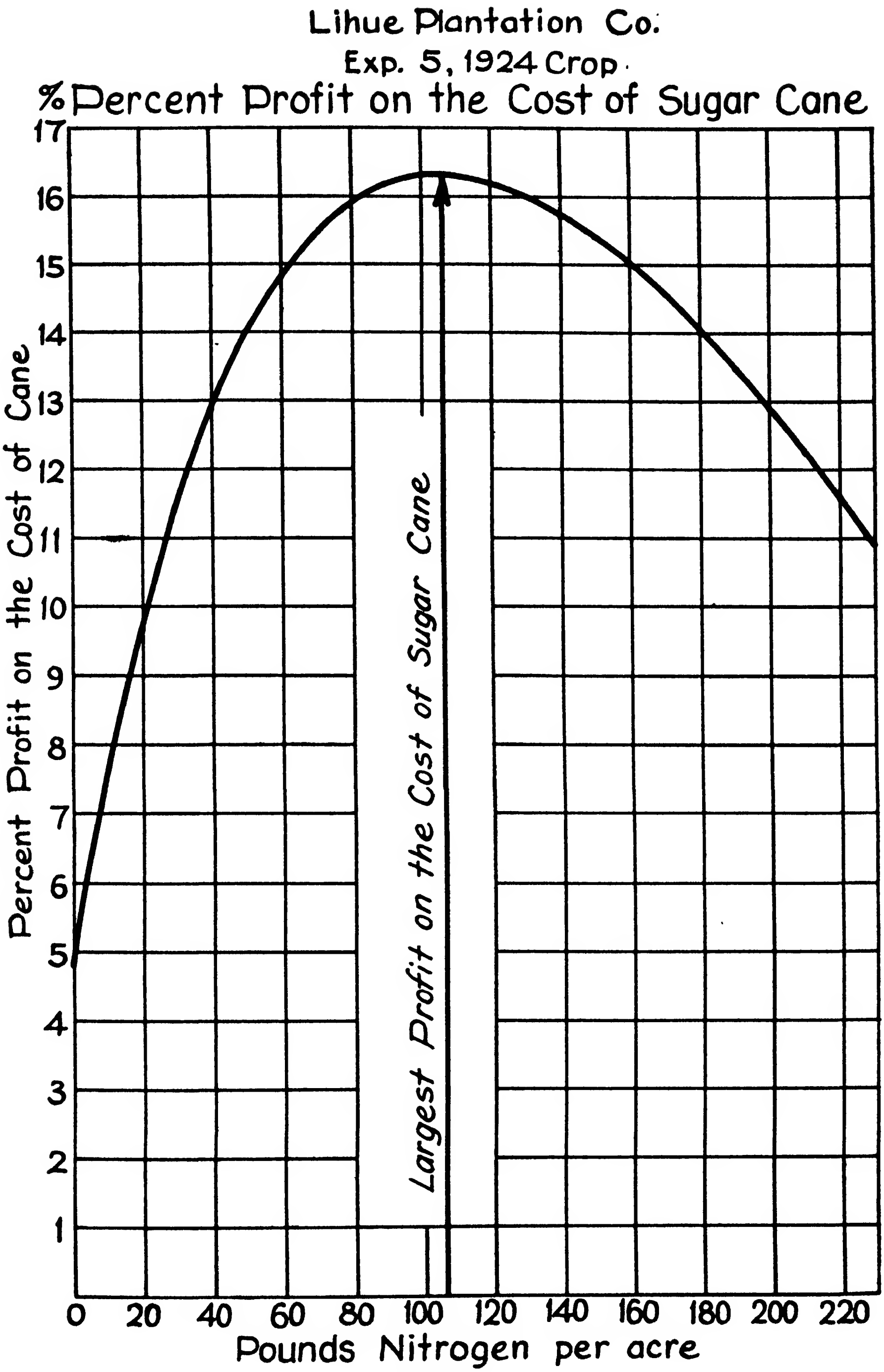

Lihue Plantation Co.
Exp. 5, 1924 Crop.
% Percent Profit on the Cost of Sugar Cane
Percent Profit on the Cost of Cane
Largest Profit on the Cost of Sugar Cane
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
20
40
60
80
100
120
140
160
180
200
220
Pounds Nitrogen per acre

Fig. 6

PIONEER MILL COMPANY, EXPERIMENT 2

Pounds Nitrogen per Acre	Tons Cane per Acre 1921 crop		Tons Cane per Acre 1923 crop
0	42.2	>	30.6
100	43.5	>	40.1
150	48.4	=	48.3
200	49.2	<	54.2
250	49.4	<	56.7

LIHUE PLANTATION COMPANY, EXPERIMENT 5

Pounds Nitrogen per Acre	Tons Cane per Acre 1922 crop		Tons Cane per Acre 1924 crop
0	34.4	>	27.3
75	44.1	>	39.8
150	49.8	=	47.9
225	49.5	<	52.9

In both cases the yields of the two successive crops happened to be approximately the same for 150 pounds of nitrogen per acre. Below this amount, the soil seems to be exhausted and above, improved. The quantity of added fertilizer that barely maintains the soil fertility unaltered may be termed maintenance fertilization. In order to maintain our yields, it is vitally necessary to apply at least the maintenance fertilization. The accurate determination of this quantity needs the use of yield equations based on many crop yields corrected for different crop lengths and climate. If the yield curves intersect at approximately a point, the maintenance fertilization can be read off the chart. From this argument, it is logical to conclude that the full effect of fertilization, either light or heavy, cannot be seen in one crop.

The yield equation is applicable to another phase of the soil-fertility question. The measure of soil fertility obtained through this channel is not the absolute quantity of plant food present in the soil but it is rather the measure of the effect of the plant food in the soil in terms of the applied fertilizer. If one ton of mill ash applied to a field affects the cane crop to the same degree as 300 pounds of potash, then the fertility of one ton of mill ash is 300 pounds of potash; yet the mill ash may contain more or less than 300 pounds of potash. In a similar way the soil fertility, S, is expressed from the effect, in terms of the applied fertilizer. The formula is

$$S = \frac{\log A - \log M}{\log R}$$

A numerical example is again cited. Oahu Sugar Company, Experiment 6, 1918 crop, has resolved into a yield curve, $Y = 112.6 - 43.5\ (0.91)^x$ in which

$M = 112.6$
$A = 43.5$
$R = 0.91$

X = lots of 90 pounds per acre of phosphoric acid in the form of reverted. Substituting these values in the formula,

$$S = \frac{\log 43.5 - \log 112.6}{\log 0.91}$$
$$= 8.8 \text{ lots.}$$

The soil in this field contains some plant food, including some phosphoric acid, equivalent, in crop producing power, to $90 \times 8.8 = 792$ pounds of phosphoric acid in the form of reverted phosphate.

The chemical analysis on the samples of soil from this field showed the presence of

0.0019% citrate-soluble P_2O_5
0.184% acid-soluble P_2O_5.

By taking the depth of 3⅓ feet as the average feeding depth of a cane crop, in this type of soil, and the weight of one acre of soil one foot deep as three million pounds, the two kinds of phosphoric acid within the reach of the cane crop are:

0.0019% of 10 million pounds = 190 pounds citrate-soluble phosphoric acid per acre; and

0.184% of 10 million pounds = 18400 pounds of acid-soluble phosphoric acid per acre.

This large amount of phosphoric acid was, in crop-producing power, equivalent to 792 pounds of phosphoric acid from the reverted. The citrate-soluble phosphoric acid in soil is thought to have the same value as phosphoric acid in the reverted form, consequently, $792 - 190 = 602$ pounds of phosphoric acid is accredited to 18,210 pounds of citrate-insoluble phosphoric acid, or, in other words, 18,210 pounds of citrate-insoluble phosphoric acid is equivalent to 602 pounds of phosphoric acid from reverted, a ratio of 100% : 3.31%. The citrate-insoluble phosphoric acid in this field may be said to change into the available form at the rate of 3.31% per crop length.

The above is to be taken as an interesting speculation only and the figure given is not to be taken as actual. This is brought out here to illustrate the many applications of the yield equation. We are starting a number of studies along these lines, and hope, later, to be able to report on the rate of plant food availability in our soils.

The application of yield equations simplifies the experiments dealing with small fertilizer differences. Usually an experiment designed to bring out the effect of a small amount of additional fertilizer does not furnish the desired results due to the unavoidable fluctuations in the fertility of the plots which mask the small differences, and to the small errors that almost always creep in when conducting field experiments. This difficulty can easily be avoided by applying the fertilizer in large steps so that the gain or loss due to the fertilizer is beyond the experimental error, and by interpolating the yield equation for the effect of a small amount of the fertilizer.

Variety comparison also has a close connection with the yield equations. It is well known that a certain variety does better than another under a given fertiliza-

tion, but when the amount of fertilizer is altered the relative values of the varieties also alter or even reverse. A fertilizer test which happened to have two varieties is Oahu Sugar Company, Experiment 3, 1918 crop. The harvesting results demonstrate the point.

Pounds Nitrogen per Acre	Tons Cane per Acre Lahaina		D 1135
0	57.97	>	55.60
75	65.78	=	65.22
150	70.51	<	72.22
225	71.02	<	76.68
300	74.10	<	78.61
375	75.01	<	84.01

The comparison of yield equations of different varieties eliminates the possible chance of overlooking a cane variety with a peculiar adaptability.

In laying out experiments for the purpose of obtaining yield equations one must endeavor to have one of the fertilizer applications less than the amount needed by the crop, another approximating the general practice, and a third in excess of crop needs; then, as before explained, by interpolating the yield equation the proper amount is quickly determined. Tentative amounts which may be used in various experiments are shown herewith.

When the response to nitrogen is not great, due to other limiting factors, the test could run 60, 120, and 180 pounds of nitrogen, or if the response is likely to be somewhat higher one could use 75, 150, and 225 pounds per acre. For plantations using 200 or more pounds of nitrogen per acre 100, 200 and 300 pounds are suggested.

When there is a question as to whether or not there is need of phosphoric acid, a series of 0, 100 and 200 pounds of P_2O_5 would give the desired information. But when assured of phosphoric acid shortage larger amounts are tried, 100, 200 and 300 pounds per acre.

Potash experiments will be of the same nature except that it may be advisable to use larger amounts of potash in fields low in potash. A series of 125, 250 and 375 pounds per acre would serve.

When it is desired to determine the degree of soil fertility by means of the yield equation it is then necessary to add a series of plots to which no fertilizer is applied.

In testing for any one plant food, it is almost needless to add that one must be sure to supply the other plant foods in sufficient quantity to prevent them from becoming limiting factors.

This brief paper on the use of yield equation has been prepared in order to show the wide application which it has in the study of experimental results.

By its use it is believed that our field experiments may be much simplified and their accuracy greatly increased.

Collection of Formulae *

(1) $Y = M - AR^{x}$

This is the fundamental yield formula of Spillman, in which

Y = yield due to soil fertility and X lots of added fertilizer;
M = the theoretical maximum yield due to soil fertility and the maximum number of lots of added fertilizer or when X becomes infinity;
A = the theoretical maximum yield due to the maximum number of lots of added fertilizer;
R = ratio of two successive increments in the crop and is, by theory, less than one;
X = the number of lots of added fertilizer, and the lots are supposed to be uniform in quantity and quality.

(2a) $\log (Y_{x+1} - Y_{x}) = \log Z = X \log R + \log A\ (1-R).$

The formula is used in evaluating A and R in (1) from the actual harvesting data. The data must have positive increments and the fertilizer must increase by a lot.

Y_{x} is the yield of plot receiving X lots of fertilizer.
Y_{x+1} is the yield of plot receiving $X + 1$ lot of fertilizer.

(2b) $M = \frac{1}{n}(\Sigma Y + \Sigma AR^{x})$

The value of M is evaluated with this formula.

n = the number of items.

(3a) $A = \frac{\Sigma Y \Sigma R^{x} - n\Sigma (YR^{x})}{n\Sigma (R^{2x}) - (\Sigma R^{x})^{2}}$

(3b) $A = \frac{n\Sigma (YXR^{x}) - \Sigma Y \Sigma (XR^{x})}{\Sigma R^{x}\ \Sigma (XR^{x}) - n\Sigma (XR^{2x})}$

When some of the increments are negative and the amount of fertilizer added is not increasing by steps of one lot each, these formulae are used to compute A and R. Various likely values of R are tried until the value of A by both formulae (3a) and (3b) become the same. M is evaluated by formula (2b).

(4) $Y = M - A\left(R_{k}^{\frac{m}{k}}\right)^{x}$

The formula is used in changing the lot of fertilizer. In the original equation a lot of fertilizer is k pounds which is changed to m pounds per lot without altering the value of the yield equation.

(5) $Y = M - \frac{A}{R^{d}}\ (R)^{x}$

The formula moves the zero point of X to the left through the distance of d. When the fertilizer is applied in such a way that the differences between successive amounts is uniform but the initial amount is not a unit dose, the example of such a case is 90, 140, 190, 240, etc., pounds, the initial dose is considered as 0, the successive lots then become 1, 2, 3, etc. The yield curve ob-

* Common logarithm only is used in this article.

tained from the adjusted lots of fertilizer is $Y = M - AR^x$. The zero point of X of this curve is in reality $\frac{90}{50} = 1.4$ lots to the right of the natural zero point, hence the zero point of X is moved 1.4 distance back to the left. 1.4 is equal to d in the formula (5).

$$(6)\quad S = \frac{\log A - \log M}{\log R}$$

The S stands for soil fertility expressed in the number of lots of fertilizer tested.

$$(7)\quad Q = -2.302585\, AR^x \log R.$$

Q is the slope of the yield equation at X.

$$(8)\quad X = \frac{\log Q - \log(-2.302585\, A \log R)}{\log R}$$

This formula is used in finding the value of X when Q is given.

$$(9)\quad X = \frac{1}{\log R} \times \log \left(\frac{-D}{2.302585\,(V + H - T)\, A \log R} \right)$$

where D = the cost of one lot of fertilizer.
V = the value of a ton of cane at the mill.
H = cost of weeding saved by one ton of cane.
T = per ton cost that varies with the tonnage of cane.

The X in this formula is the number of lots of fertilizer needed to produce the cane crop so as to secure the maximum profit per acre.

$$(10a)\quad \left(F + G - \frac{D}{2.302585 \log R} \right) \times \frac{2.302585\, A \log R}{-DM} + \frac{(2.302585\, A \log R)}{-M} X = L$$

$$(10b)\quad \left(\frac{1}{R} \right)^x = U$$

where F = fixed charge per acre per crop length.
G = cost of keeping one acre of bare ground free of weeds for one crop length.
D = the cost of one lot of fertilizer.

The values of L and U are computed with the arbitrary values of X, and the resulting lines are plotted. The value of X at the intersection of the lines is the number of lots of fertilizer to use in order to obtain the highest profit per dollar invested in the crop.

Of these formulae, 4, 5, 6, 7, 8, 10a and 10b have been developed by the agricultural department of the Experiment Station, H. S. P. A., and 1, 2a, 2b, 3a, 3b and 9 are either due to Spillman or modifications of his formulae.

For additional formulae see "The Law of Diminishing Returns" by Spillman and Lang.

Acknowledgment is made to Professor J. S. Donaghho for his kind assistance in verifying the formulae developed by the agricultural department of the Experiment Station, H. S. P. A.

The Influence of Weather on the Production of Sugar in a Typical Unirrigated Plantation of Hawaii

PEPEEKO SUGAR COMPANY

By U. K. Das

Introduction

The influence of weather on agricultural crops is universally recognized. All of us are familiar with such terms as good and bad weather in relation to particular crops. This influence is more marked in places where the range of variation of the climatic factors is comparatively greater than in places like Hawaii where the climate is equable throughout the year. But even in Hawaii the weather conditions vary from year to year. It is the purpose of the present paper to study the extent to which these variations in weather conditions have affected the sugar crops of Hawaii.

Previous Works

The relation between weather condition and crop yield has been studied in almost every progressive country. Such studies relating to the yield of sugar have begun in a systematic manner only in recent years. However, as far back as 1906, Jorgensen (1) in St. Croix, found an important relation between the yield of sugar and summer rainfall of a year before. His study was of a very general nature. Coming to the recent years, exhaustive studies, employing the statistical methods, have been made by Koenig (2) in Mauritius, Tengwall and Van Der Zyl (3) in Java, and MacDonald (4) in Louisiana. All these studies brought out the fact that weather conditions were greatly responsible for the variation in the yields from year to year.

In Hawaii, the weather has never been studied in its relation to the production of sugar, probably because of the belief that weather conditions in these Islands do not vary considerably from year to year to be of any great significance to the sugar industry, except in the case of pronounced drought or very excessive rainfall. In Hawaii, again, the conditions of sugar production are very different from those obtaining in countries like Java, Louisiana or Mauritius. In these Islands a crop is about two years in producing and includes both plants and ratoons. Again, of the total annual production of these Islands, more than half the amount is made in the irrigated plantations. The progressiveness of the industry tends to make it independent of the vagaries of weather.

The yield of sugar per acre in Hawaii has increased considerably from 8960 pounds in 1905 to 12,740 pounds in 1925, and 13,300 pounds in 1927. This increased yield has no doubt been brought about by a better utilization of our knowledge of the sugar cane plant, of the soil, fertilizers, water, better organization of labor and also more efficient methods of manufacture. However, while maintaining this trend of increasing yield over a period of years, the production of sugar

in the individual years shows great fluctuations. As it is not conceivable that our methods both in the field and the factory change so abruptly from year to year, and to such a great degree, the cause of these fluctuations must be sought somewhere else. In the present paper these annual variations have been analyzed in relation to the variations in the weather conditions in order to discover if there is any definite correlation between weather conditions and yield of sugar per acre.

The annual yields of Pepeekeo Sugar Company have been taken as the subject of study. This has been done for several reasons: (1) Pepeekeo is a typical unirrigated plantation, and as such the influences of both rainfall and temperature on crop yields are likely to be more clearly seen; (2) there has not been any sudden and revolutionary change at Pepeekeo either in the field or in the factory. The land area and the variety of cane grown are about the same in all the years studied.

Pepeekeo Sugar Company is situated on the windward side of the island of Hawaii. The area under any crop is about 2000 acres, and is spread mostly on the slopes of mountains. Yellow Caledonia has been and is still the principal variety of cane. The harvesting season begins in January or February, and continues up to July or August with occasional interruptions caused by extremely unfavorable weather. The harvest includes ratoons and plant canes, and the crop is usually about two years in the field. The cultural practices are about the same as in the other up-to-date plantations, with only one outstanding difference which is that at Pepeekeo all the trash has been returned to the soil since 1905.

NORMAL RAINFALL AND TEMPERATURE

TABLE I

Inches	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Rainfall....	13.39	8.41	14.44	12.03	8.78	7.62	9.18	11.20	11.48	10.16	13.45	12.33	132.47
Temperature F°...	70.1	70.4	70.3	71.2	72.5	73.1	74.3	74.9	75.1	74.5	73.1	71.6	72.5

The average annual precipitation of Pepeekeo for 1905-1925 inclusive is 132 inches and the annual temperature 72.5° F. The average monthly rainfall and temperature for the 21 years are given in Table I, and the same data presented in a graphical form in Chart A. The data have been obtained from the records of the U. S. Weather Bureau Station at Honolulu.

Chart A reveals several interesting points. It is seen that at Pepeekeo, the month of December is warmer than April, that the months of January-March constitute the winter months, and the months of August-October the summer months. Rainfall is generally high in winter and low in summer, but unlike many other plantations there is a general increase of rainfall after the month of June and towards the approach of the warm months of August and September.

The monthly precipitation and temperature for the individual years from 1905 to 1925 are given in Tables II and III. The records are expressed as departures in inches rainfall or degree temperature, the departures being calculated as above (+) or below (—), the average of the 21-year period.

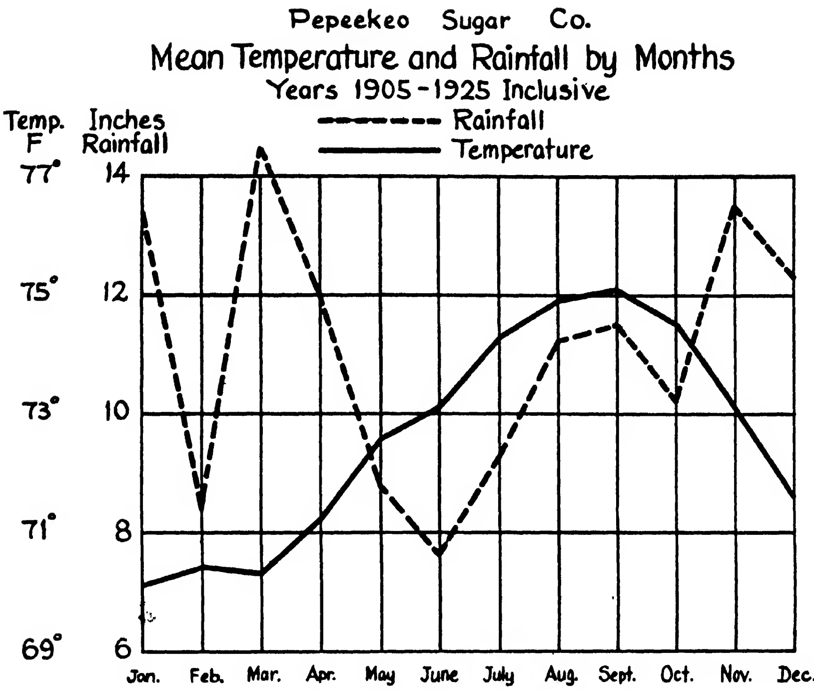


Chart A

TABLE II
TEMPERATURE DEPARTURES
Pepeekeo Sugar Company

Year	January	February	March	April	May	June	July	August	September	October	November	December
1905..........	— .7	— .4	+ .2	— .3	— .3	+ .3	+1.3	+1.3	+1.2	+ .4	+ .3	+ .2
1906..........	+1.1	+1.0	— .5	+1.0	+ .5	+1.1	+ .9	+ .9	+ .9	+1.3	+1.1	+1.0
1907..........	+2.3	+1.2	— .1	0	+1.4	0	+2.6	+1.1	+1.1	+1.1	+ .9	+1.1
1908..........	— .1	— .8	+ .9	— .6	+1.1	—1.7	—2.5	—2.3	—1.9	—1.3	+ .8	0
1909..........	+1.3	+1.2	+1.0	+ .2	— .8	+ .3	— .5	— .7	— .9	+ .1	+ .8	+ .5
1910..........	— .9	— .7	+ .2	—1.0	— .5	— .7	— .6	— .1	+ .5	— .3	+ .1	— .2
1911..........	— .4	— .8	+ .2	+ .5	+ .1	+ .1	+ .1	+ .7	— .6	— .2	— .3	— .8
1912..........	+ .5	+ .5	—1.5	— .2	— .7	— .2	+ .1	+ .4	+ .5	+ .6	+ .8	— .2
1913..........	+ .6	+1.2	+1.3	+ .2	— .1	+ .8	+ .6	+1.3	+ .8	+1.6	+ .3	+ .6
1914..........	— .5	+ .1	+ .4	+ .8	— .6	— .3	+ .6	+ .5	+ .3	+ .5	+ .8	— .1
1915..........	+ .1	—1.8	+ .6	+ .6	+1.9	+2.1	+1.1	+1.3	+1.6	+ .5	— .5	+ .9
1916..........	+1.5	+1.8	+2.2	+1.0	+2.1	+ .3	0	— .7	0	+ .1	— .5	— .1
1917..........	— .3	— .2	+ .1	— .1	— .6	— .9	+ .3	+ .7	— .9	—2.5	—2.1	—2.2
1918..........	—2.4	—4.2	—3.9	—3.1	—2.9	— .5	—1.1	—1.5	— .9	— .3	—1.2	—2.2
1919..........	—2.3	— .4	—1.9	—1.0	—2.0	—1.1	—1.5	—2.1	—1.9	—1.7	—1.9	—1.6
1920..........	—1.0	— .8	— .6	— .7	+ .3	—2.5	—3.6	—2.2	—1.7	—2.5	—2.9	—2.8
1921..........	—2.2	+1.5	+ .9	0	— .3	+ .3	— .5	—2.3	—2.3	—1.1	+ .7	+ .1
1922..........	+ .9	0	+ .1	+ .8	— .7	— .7	+ .3	+ .3	— .3	+ .9	— .7	+1.1
1923..........	— .5	—1.3	— .8	— .3	+ .3	+ .5	+ .7	+1.3	+1.7	+1.9	+1.4	+ .5
1924..........	+ .5	+ .4	+ .7	+1.6	+ .8	+1.1	+ .5	+ .9	+1.0	+ .6	+1.9	+2.8
1925..........	+2.2	+1.6	+ .7	0	+ .8	+ .7	+ .9	+ .8	+1.1	+1.1	+ .9	+2.0
1926..........	+2.6	— .5	+ .9	+ .6	+1.0	+1.9	+1.4	+1.1	+ .7	+ .9	+ .9	+ .9
1927..........	+ .7	+2.0	+1.3	+1.6	+ .7	+1.9	.....	.....	.....	.....	.....	.....
Normal Tempertures (1905-1906).	**70.1**	**70.4**	**70.3**	**71.2**	**72.5**	**73.1**	**74.3**	**74.9**	**75.1**	**74.5**	**73.1**	**71.6**

TABLE III
RAINFALL DEPARTURES
Pepeekeo Sugar Company

Year	January	February	March	April	May	June	July	August	September	October	November	December
1904	+10.85	+ .18	—13.06	+12.03	— 1.63	—1.33	+ .93	+ 5.12	— 3.16	— 6.37	— 6.66	— 8.01
1905	— 8.96	— 2.53	— 7.26	— 5.03	— .43	— .86	+ .17	+ 1.43	+ 2.81	— .72	+11.19	— 1.46
1906	— 8.86	— 6.64	—10.44	— 5.77	— .92	— .96	— .17	+ 6.23	— 3.35	— 6.32	+ 2.43	+ 1.20
1907	— 7.46	— 4.72	— 3.03	— 5.70	— 3.43	+1.44	+ .58	+17.11	+13.28	+ 4.54	— 3.25	— 7.29
1908	— 6.30	+14.50	— 7.75	+ 2.18	— 3.15	—2.31	— 3.31	— 2.83	+ 1.26	+ .10	— 4.78	+ 1.58
1909	— 6.31	— 2.26	+16.33	+ .45	+ 2.08	—1.98	+ 3.09	— 5.36	— 2.41	— 4.26	—10.42	+ 6.74
1910	+ 6.39	— 3.54	— .53	— 5.48	+ .51	+3.48	— 1.51	+ 2.39	— 7.03	— 2.33	— 2.99	+ 4.68
1911	+ 1.95	+ 4.11	— 2.63	+ .03	+ 7.57	+3.09	— .83	— 3.87	+ 3.42	— 1.53	— 1.32	— 2.73
1912	—12.44	+ 1.67	— 2.69	+ 3.86	— 1.79	+1.19	— 4.08	— 4.03	— 5.92	+ 5.76	— .42	+ 4.84
1913	+18.47	— 2.71	— 8.30	— 2.36	— 1.04	+ .24	— 3.18	— 4.63	— 6.19	— 4.69	+ 6.43	— 2.89
1914	— 4.91	— 3.52	— 5.05	— 3.85	+13.50	+8.30	+10.04	+18.55	+16.07	— 1.96	+ 2.14	— 1.97
1915	— 9.41	— 1.21	—11.70	+ 9.14	— 5.52	+3.09	— .23	— 5.99	— 4.22	+ 3.15	+21.29	+ 2.67
1916	— 2.33	— 7.23	— 4.43	+ .12	+ 9.52	+1.19	— 1.61	+ 1.50	+ 1.14	+ 1.92	— .51	+15.74
1917	+ .65	— 4.40	+ 6.02	+ .64	— .29	+ .21	— 3.18	— 7.14	— 7.52	— 7.29	+ 1.59	— 4.73
1918	+ 7.41	+18.36	+ 9.60	+10.95	+ .28	—2.82	+11.76	— 1.63	— 5.33	— 1.81	— 3.25	+ 2.51
1919	— 8.76	— 2.18	— 3.98	— 6.11	— 3.82	—2.41	— 2.91	— 2.05	— 4.61	— 1.18	— 7.93	— 8.77
1920	— 7.91	— 4.26	+ 9.33	— 5.92	— 6.56	—4.13	— 2.43	— 4.67	+ .88	+11.46	— 6.39	— .66
1921	+19.89	— 3.32	— 8.68	— 1.79	— 4.64	—3.37	— .54	— 1.92	— 5.59	+ 2.43	+ 7.35	+ 4.19
1922	+ 9.98	+ 9.24	+20.43	+ .67	— 1.40	—5.31	— 2.76	— 4.10	+ 6.87	— 3.22	+ 5.17	— 8.43
1923	+29.97	— .87	+ 9.27	+10.53	— .35	+ .46	+ 3.12	+ .64	+ 6.47	+ 4.25	— 7.44	+14.70
1924	— 9.19	— 1.39	— 5.80	+ 6.25	— 1.84	—4.34	+ 2.99	— .84	— 3.22	+ 6.76	— 7.12	— 8.73
1925	— 1.91	— 6.20	+11.26	— 2.88	+ 2.62	+ .26	— 4.78	+ 1.20	+ 2.56	— 5.08	— 2.75	—11.19
1926	— 9.11	— 2.47	—12.23	— 8.30	— 2.88	—4.89	— 4.01	+ 4.01	— 2.31	— 4.28	— 8.31	+ .75
1927	— .40	— 5.45	+ 4.81	— 1.04	+ 1.91	—2.39	....	....	....	....	....	....
Normal rainfall (1905-1925)	13.39	8.41	14.44	12.03	8.78	7.62	9.18	11.20	11.48	10.16	13.45	12.33

Sugar Yields at Pepeekeo

In Table IV are given the area harvested, the predominant variety and yield obtained. It will be seen that there is no great fluctuation in the area harvested or the variety of cane grown. The yield of sugar per acre is shown graphically in Chart B for the 20-year period including 1906-1925. The curve shows a general upward trend, but at the same time fluctuates greatly from year to year.

As has been stated before, the increase in yield from 1906-1925 has been brought about by several factors, all of which can be included in the term "progressiveness." It is therefore impossible to compare the yield per acre of 1905 with the yield per acre of 1925 on the basis of absolute figures. To eliminate the influence of this trend of increased sugar production and to bring about clearly the fluctuations from year to year, the yields of the individual years are expressed as departures from a normal.

The study is begun with 1906, because temperature data prior to 1905 are not available. This period of 20 years from 1906-1925 is divided into four groups of five years,—each group consisting of five consecutive years. The yields of the individual years are calculated as departures above or below the average of the 5-year group to which these years belong.

Table V gives the departures calculated in this manner. Chart C is a graphical presentation of the same information.

TABLE IV

AREA AND CANE YIELD

Year	Area in Acres	Predominant Variety	Crop Yield in Lbs. p. a.	Polarization Per Cent Cane
1905	1914	Yellow Caledonia	6,444	.....
1906	1809	"	7,160	.....
1907	1914	"	6,977	13.96
1908	1700	"	8,928	13.45
1909	1886	"	7,288	.....
1910	1986	"	7,061	13.80
1911	2042	"	7,762	13.21
1912	1969	"	8,135	13.23
1913	2013	"	8,894	13.54
1914	1877	"	10,449	13.55
1915	1976	"	12,094	13.05
1916	1861	"	10,044	13.17
1917	1994	"	11,074	13.25
1918	1926	"	8,598	12.57
1919	2004	"	9,069	12.97
1920	1897	"	10,320	12.85
1921	2001	"	10,420	12.15
1922	1921	"	10,505	11.70
1923	1977	"	9,650	12.37
1924	1850	"	11,758	12.70
1925	2065	"	13,788	12.21
1926	1877	"	13,480	12.45
1927	.....	..	.....	11.29*

* Figures to August only.

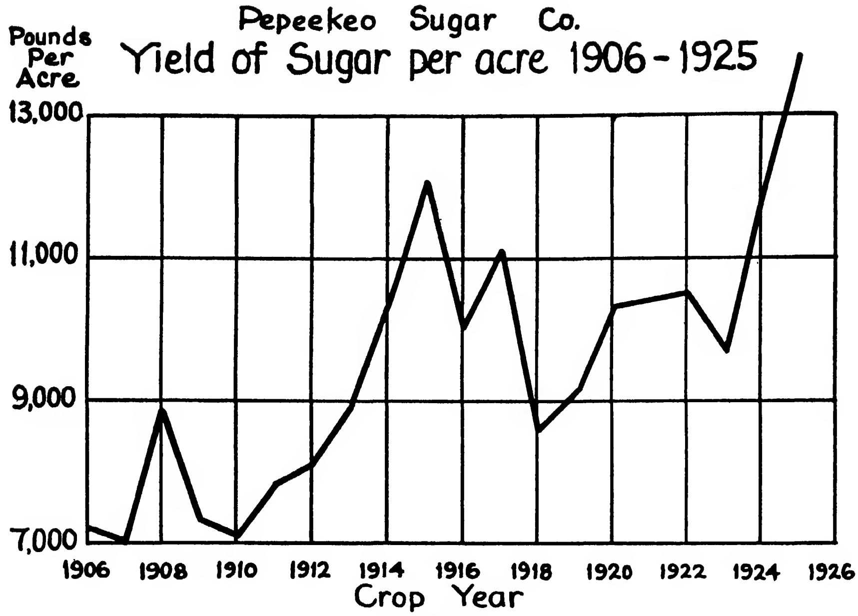


Chart B

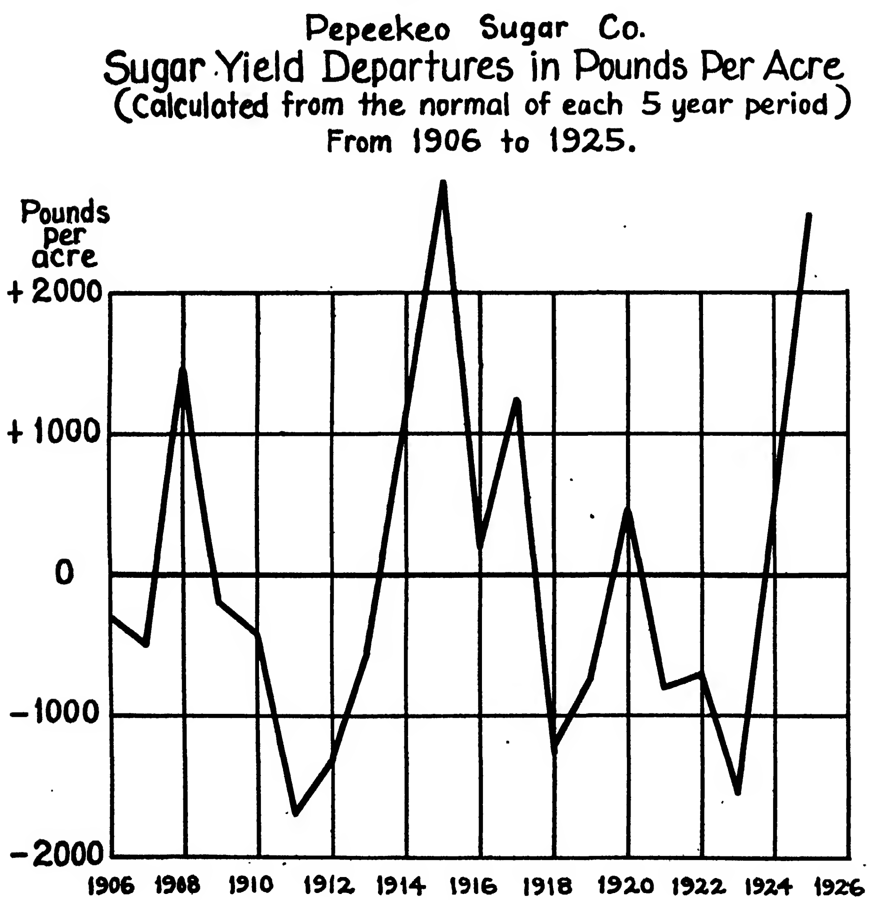


Chart C

TABLE V

SUGAR YIELD DEPARTURES

Year	Sugar Yield in Lbs. p. a.	Average of 5 Years, Lbs. p. a.	Departures, Lbs. p. a.
1906	7,160		— 323
1907	6,977		— 506
1908	8,928	7,483	+1445
1909	7,288		— 195
1910	7,061		— 422
1911	7,762		—1705
1912	8,135		—1332
1913	8,894	9,467	— 573
1914	10,449		+ 982
1915	12,094		+2627
1916	10,044		+ 223
1917	11,074		+1253
1918	8,598	9,821	—1223
1919	9,069		— 752
1920	10,320		+ 499
1921	10,420		— 804
1922	10,505		— 719
1923	9,650	11,224	—1574
1924	11,758		+ 534
1925	13,788		+2564

TABLE VI

MONTHLY RAINFALL AND TEMPERATURE FOR HIGH YIELD AND LOW YIELD YEARS

		Inches Rainfall		Degrees Temperature	
		High Yield Years (1908, 15, 17, 25)	Low Yield Years (1911, 12, 18, 23)	High Yield Years	Low Yield Years
Two years previous	May	6.82	10.65	73.2	72.6
	June	8.33	7.45	74.3	73.2
	July	9.07	8.99	75.1	73.8
	August	10.26	10.33	76.1	74.0
	September	9.66	8.01	76.4	74.2
	October	9.76	9.60	75.8	74.2
	November	19.13	11.81	73.7	73.4
	December	16.25	20.17	72.4	71.7
Previous year	January	7.42	18.13	71.1	69.9
	February	6.48	9.76	71.5	70.0
	March	9.86	20.26	71.1	70.5
	April	11.24	11.00	72.1	71.3
	May	13.22	10.36	73.4	72.1
	June	9.27	7.99	73.5	72.6
	July	12.13	7.11	75.5	74.3
	August	20.28	8.02	75.4	75.3
	September	18.45	10.42	75.9	74.8
	October	12.98	6.57	75.0	74.0
	November	11.27	14.06	73.9	72.4
	December	11.77	9.53	72.5	71.1

Crop year	January	9.15	20.11	70.6	69.4
	February	9.08	14.23	70.1	69.0
	March	13.90	17.83	70.9	68.8
	April	14.30	18.37	71.2	70.4
	May	7.20	10.21	73.3	71.7
	June	7.93	9.51	73.2	73.1
	July				

High Yield and Low Yield Years

It is seen from Table V and Chart C that the four years, 1908, 1915, 1917 and 1925, have been very good, yielding more than 1000 pounds sugar per acre than the average of the group, and the four years, 1911, 1912, 1918 and 1923, have been unusually poor, yielding less than the average of the group by more than 1000 pounds per acre. These two groups of high yield and low yield years have been analyzed as to the weather conditions prevailing during the growing period. As the crop is usually two years old, the average monthly temperature and rainfall data have been obtained for the entire period of two years and even longer. In Table VI are given the average monthly temperatures and rainfall obtaining during the growing period of the two groups of years. In Charts D and E the same data are shown by curves.

A study of Chart D shows that for the high yield group of years the temperature has been consistently higher than the temperature of the corresponding months in the low yield group. This is true not of one month, but every single month in the two-year period—an information of unusual interest. The greatest difference

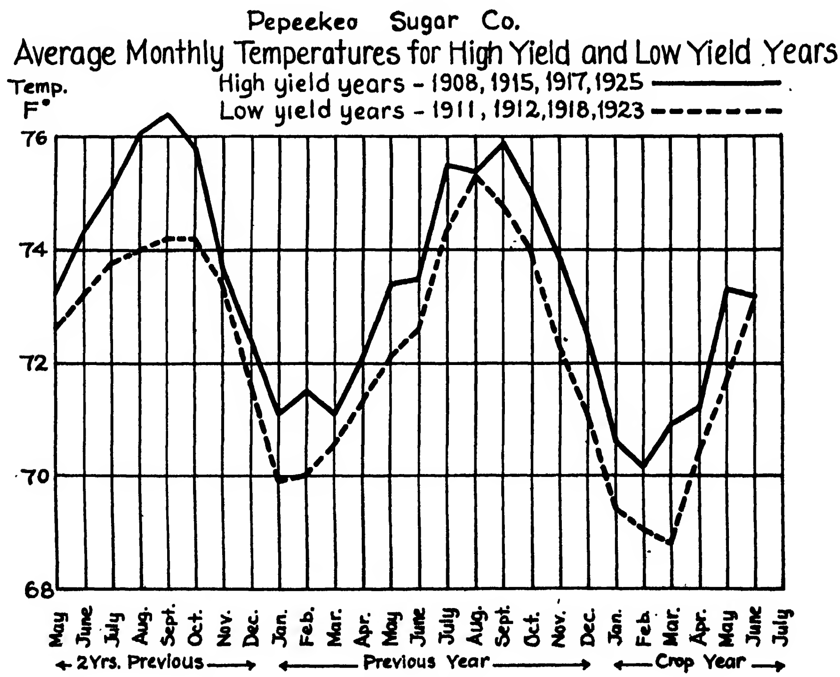


Chart D

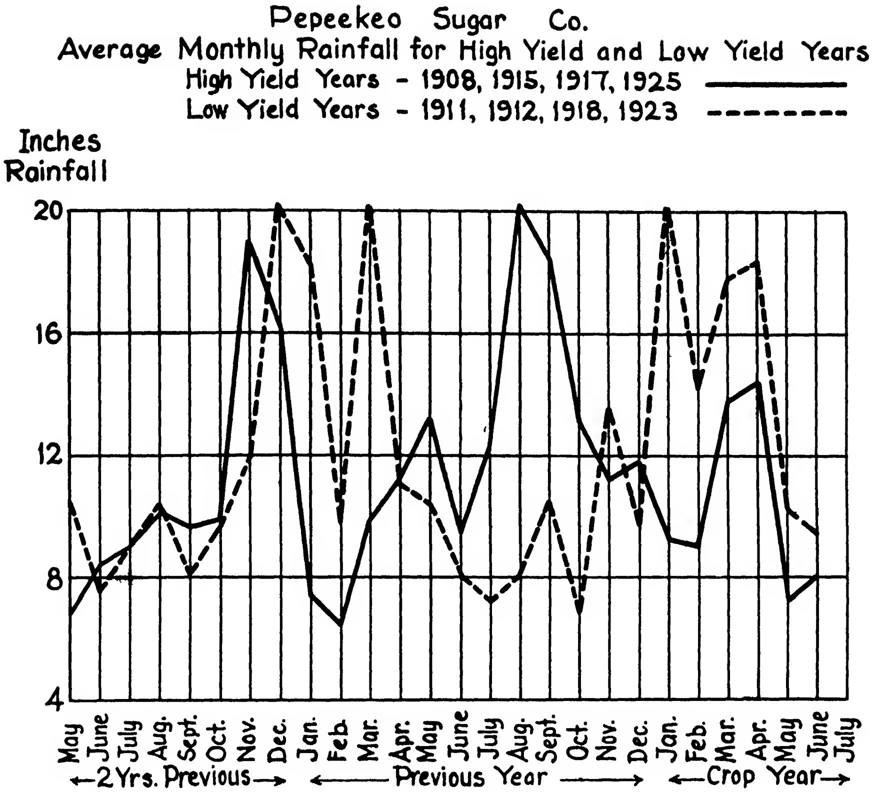


Chart E

does not, however, come either in the crop year or the year previous, but in the warm months of August, September and October, two years previous. This fact is of great significance, because it seems to indicate the good effects of warm conditions in the early stages of the cane crop. It will be remembered that at Pepeekeo the harvest begins towards the end of January and ends in August; therefore, the ratoons as well as the plant cane are all young in the months of August, September and October.

A study of Chart E reveals the fact that the high yield years have had exceptionally well distributed rainfall, while in the low yield years the rains came when they were least desired.

We have noticed that at Pepeekeo rainfall is very high in the cold winter months of January and March. Against an average temperature of 70.5° F. in January and March, we have a rainfall of about 14 inches per month. When the cane is very young this high rainfall, together with the cold temperature, is likely to produce a wet and damp condition injurious to the health and activity of plants.

In the months of January and March of the previous year, the poor yield years have unusually high rainfall, more than 20 inches per month against a rainfall of about 7 inches per month in the corresponding period of the good yield years, while temperatures for these months have been lower in the poor yield years than the temperature in the same months in the good yield years.

In the months of May to October, inclusive, of the previous year, the good yield group have a much higher rainfall than in the corresponding months in the low yield group. The usually warmest month of August has more than 20 inches of rain in the good yield group, and only 7 inches in the same month of the poor yield group.

In the ripening and harvesting season beginning from January of the crop year, the good yield years, as is to be expected, have a much lower rainfall than in the corresponding months of the poor yield years.

Thus we see that the conditions of temperature and rainfall in the good yield years have been exactly what we would have ourselves prescribed if we had control over these two weather factors.

Correlation Studies

In order to bring out more clearly the influence of the different months in the making of a crop, the statistical methods of correlation have been employed. For the theory and evolution of these methods the reader is referred to some standard books on statistical methods. An excellent interpretation of these methods is given in Babcock and Clausens' *Genetics in Relation to Agriculture* (published in 1918 by McGraw-Hill Book Company).

If there is any direct and linear correlation between two phenomena, then it is possible to express that correlation by what is known as the "co-efficient of correlation."

Both the magnitude and the sign of this co-efficient are of importance. A perfect correlation, rarely obtained in agricultural operations, is expressed by the highest possible co-efficient, 1.0. If the co-efficient is more than 0.5, then the two variables are believed to be definitely correlated. If the co-efficient lies between 0.3 and 0.5, the correlation is believed to be low, but still of some significance. Co-efficients below 0.3 are regarded to signify doubtful or very low correlation.

If the co-efficient has a + sign preceding it, the variables are positively correlated, i. e., any increase or decrease in one variable will follow an increase or decrease in the other variable. If the sign is —, then the variables have a negative or opposite correlation.

In the study of agricultural crops the co-efficient of 0.5 or more is believed to be of "critical" significance. That is, if it is found that the temperature or rainfall at any period has a co-efficient of correlation of 0.5 or more, then that period is regarded to be of critical importance to the crop. The good or bad conditions in that period are likely to leave a permanent stamp on the crop correlated.

The method of finding the co-efficient is the one used by Babcock and Clausen in their *Genetics in Relation to Agriculture,* referred to previously. An illustration is given in Table VII. The co-efficient of correlation has been worked out for temperature in the month of August and sugar yield in the crop year two years following:

TABLE VII

Calculation of Co-efficients of Correlation Between Temperature Departures in the Month of August and Sugar Yield Departures for the Crop Harvested Two Years Later.

Sugar yield departures (in Hundred lbs.) ⟶ x

Temperature departures ⟶ y

y \ x	-20	-16	-12	-8	-4	0	4	8	12	16	20	24	28	fy	d'y	fd'y	fd'²y	{d'xd'y}
3																		
2				1	1				1			2		5	+1	5	5	88
1				2		1	1	1	1					6	0	0	0	0
0		2												2	-1	-2	2	16
-1	1						1							2	-2	-4	8	0
-2		1		3										4	-3	-12	36	24
-3																		
fx	1	3	0	6	1	1	2	1	2	0	0	2		19		$\frac{-13}{19}$	$\frac{51}{19}$	$\frac{128}{19}$
d'x	-12	-8	-4	0	4	8	12	16	20	24	28	32						
fd'x	-12	-24	0	0	4	8	24	16	40	0	0	64						
fd'²x	144	192	0	0	16	64	288	256	800	0	0	2048						

$wy = -.68$
$w^2y = .46$

$= 2.68$
$\underline{.46}$
2.22
$\delta y = \sqrt{2.22}$
$= 1.49$

$= 6.74$
$wxwy = \underline{-4.29}$
11.03

$\frac{120}{19} = wx$
$= 6.32$
$w^2x = 39.94$

$\delta x \delta y = 18.88$

$\frac{3808}{19}$
$= 200.42$
$\underline{39.94}$
160.48
$\delta x = 12.67$

$r = \frac{11.03}{18.88}$
$= +.58$

Co-efficient of Correlation (r) = +.58

TABLE VIII

CO-EFFICIENTS OF CORRELATION BETWEEN TEMPERATURE, RAINFALL AND SUGAR YIELD

	Months	Mean Temperature and Sugar Yield	Rainfall and Sugar Yield	Maximum Temperature and Sugar Yield
Two years ago	May	—.04	—.08	.09
	June	+.32	.19	.40
	July	.32	.12	.51
	August	.58	.01	.38
	September	.53	.03	.54
	October	.50	.01	.49
	November	.29	.26	.13
	December	.34	—.01	.10
One year ago	January	.23	—.14	.24
	February	.32	—.28	.33
	March	.18	—.38	.20
	April	.37	.04	.31
	May	.29	.26	.16
	June	.23	.11	.07
	July	.26	.34	.21
	August	.22	.55	.19
	September	.35	.43	.13
	October	.42	.36	.21
	November	.35	—.10	.29
	December	.37	—.03	.38

Crop year	January	.32	—.42	.24
	February	.13	—.29	.14
	March	.36	—.02	.44
	April	.29	—.08	.41
	May	.40	—.07	.47
	June	.27	.07	.16

The crop yields for the years 1906-1925 have been correlated in the manner shown above for every month and for both the weather factors, namely, temperature and rainfall. The co-efficients are given in Table VIII, and represented graphically in Chart F.

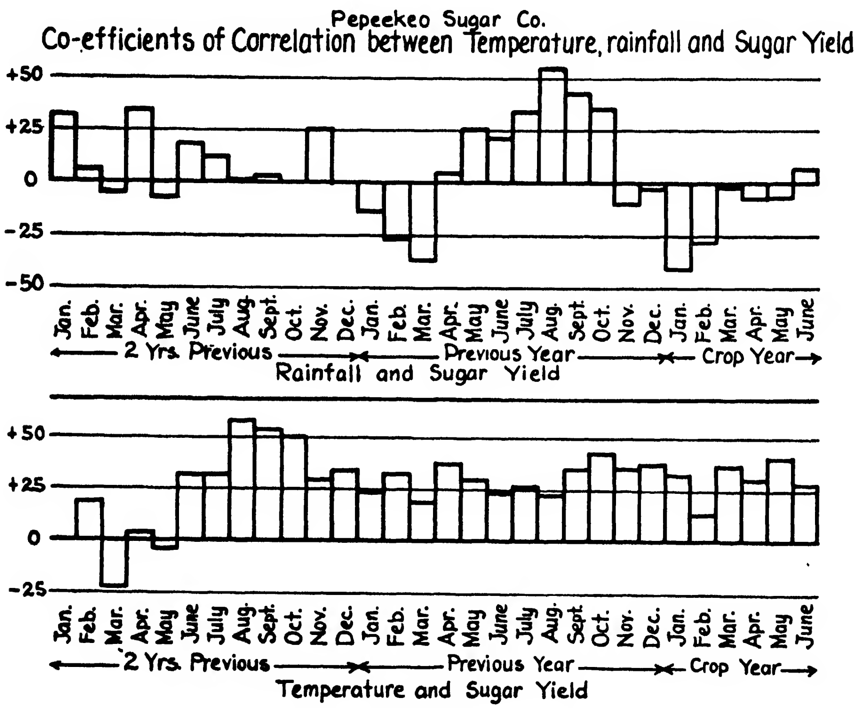


Chart F

Temperature and Crop Yield

It is seen, and as has already been suggested by Chart D, that temperature has a significant positive correlation throughout the entire crop period. For every month beginning in April, two years previous, any increase in temperature over normal tends to increase the production of sugar per acre. In other words, at Pepeekeo warm temperature in relation to a particular crop is always beneficial no matter when it comes.

There are also found to be three critical periods so far as temperature is concerned. These are the months of August, September and October, two years previous. Thus, for the crop of 1925, the months of August-October, of 1923, will be of "critical" value. This should not cause surprise. These months seem

to be so removed from the actual harvest time that on a cursory examination we are not likely to attach much importance to these. However, as an eminent English meteorologist has said, in connection with the agricultural crops of England, we are likely to "credit the plants with too short memories." But a crop "never forgets and hardly ever forgives the treatment which it has received" in a previous season. As we have stated before, the months of August, September and October, two years previous, in relation to a particular crop, happen to be the months when the cane is young and the rate of growth is active. A good temperature means a good, early start; and good growing conditions during the early and formative period are always of great importance not only to the cane plant but also to all living organisms.

Rainfall and Crop Yield

When we come to study the co-efficients of correlation between monthly rainfall and crop yield, we find that our conclusions derived from Chart E are fully justified.

The winter months of January, February and March, of the previous year, have a negative correlation, i. e., high rainfall lowers the yield. The summer months have a positive correlation and negative correlation is again evidenced in the ripening and harvesting season.

Therefore, for an ideal distribution of rainfall, we must have low rainfall in the winter months of December-March, and high rainfall in the summer months of the previous year, and low rainfall again in the ripening and harvesting months of the crop year. This ideal is realized in the case of high yield years as we have already seen.

For rainfall, there is only one month which is of "critical" importance. It is the month of August—usually the warmest month—of the previous year. That high rainfall in a period of high temperature will increase growth and permanently influence the crop yield is evident on the very face of it.

Maximum Temperature and Crop Yield

Koenig (2) has found that in Mauritius the sugar yield appears to have a better correlation with maximum temperature than with mean temperature. To find out if such a condition exists at Pepeekeo, the sugar yields have been correlated with monthly maximum temperature. The co-efficients are given in Table VIII. It is seen that monthly maximum temperature has about as great a significance as monthly mean temperature. All of which tends to accentuate the importance of high temperature at Pepeekeo to the production of high yields. The co-efficients are not, however, of any greater significance than those obtained from mean temperature. The mean monthly temperatures at Pepeekeo can therefore be accepted as correct indication of weather conditions.

Total Warmth and Sugar Yield

As has been suggested by the co-efficients of correlation between mean temperature and sugar yield, an increased temperature in any of the 24 months begin-

ning with June, two years previous, and ending with May of the crop year, will enhance, to a certain degree, the yield of sugar. We would, therefore, expect that if we could express quantitatively the total warmth received by any crop, then, we could explain the periods of low and high yield on the basis of the total warmth.

To this end, we have used in this paper a term "day-degree," adopted very widely by the British weather authorities. In our case a day-degree is defined as one degree Fahrenheit temperature above 60° operating for one day. A day having a mean temperature degree of 70° will, therefore, have a value of 10 day-degrees. It is assumed here that cane grows very little or not at all below a daily *mean* temperature of 60° F.

The total day-degrees corresponding to a particular crop year are, therefore, calculated by adding the day-degrees for each month. In Table IX the day-degrees or total warmth corresponding to the crop years are given. In Chart G are plotted the same data.

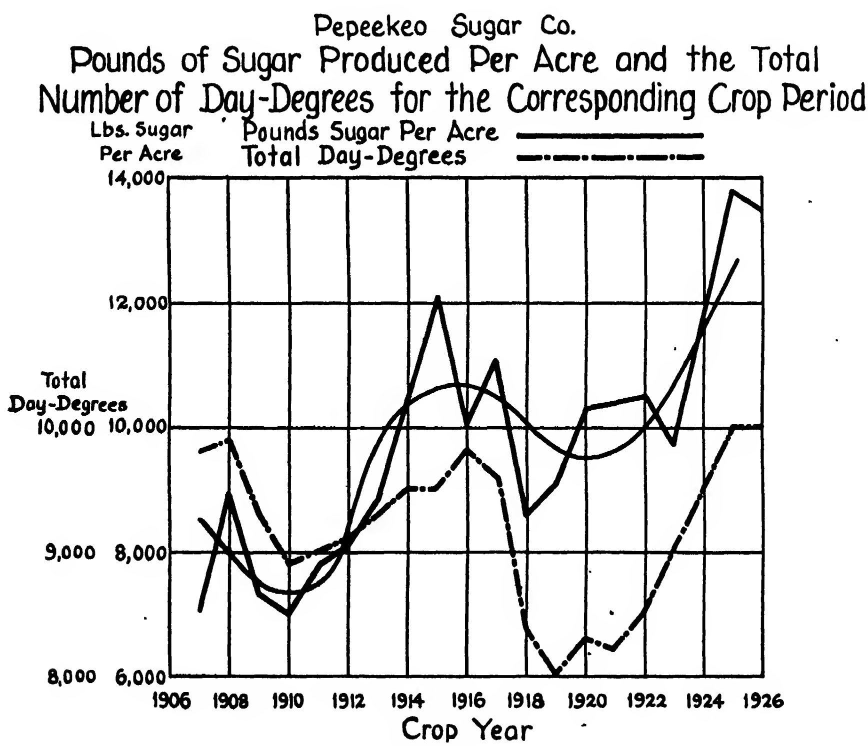


Chart G

TABLE IX

YIELD OF SUGAR PER ACRE AND THE TOTAL NUMBER OF DAY-DEGREES IN THE CORRESPONDING CROP PERIOD

Year	Pounds Sugar per Acre	Total Day-Degrees
1907	6,977	9,818
1908	8,928	9,901
1909	7,288	9,343
1910	7,061	8,916
1911	7,762	9,053
1912	8,135	9,107
1913	8,894	9,312
1914	10,449	9,546
1915	12,094	9,509
1916	10,004	9,795
1917	11,074	9,591
1918	8,598	8,389
1919	9,069	8,004
1920	10,320	8,287
1921	10,420	8,193
1922	10,505	8,513
1923	9,650	9,032
1924	11,758	9,548
1925	13,788	10,027

Pepeekeo Sugar Co.
Monthly Temperature Departures for High Yield and Low Yield Years
(Expressed in terms of accumulated day-degrees)

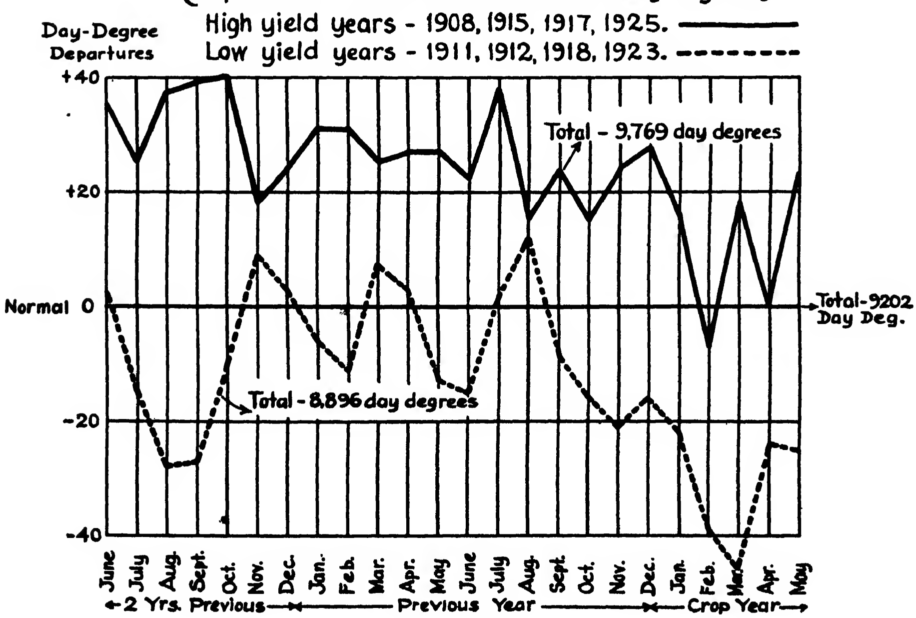


Chart H

As was expected, we find that the total warmth or total number of day-degrees bears a striking relationship to periods of high and low yield. From Chart G we see that the low yield periods from 1908 to 1912 and from 1918 to 1923 correspond with two periods having comparatively low total warmth. The periods of high yield coincide with periods of high total warmth. The relationship is better brought out by studying the smooth curve which represents the trend of sugar yield from 1906-1925.

The normal monthly day-degrees are obtained from the average monthly temperature of the years 1905-1925. If we now take the high yield years at Pepeekeo, namely, the years 1908, 1915, 1917 and 1925, and the low yield years, 1911, 1912, 1918 and 1923, and calculate for every month the day-degrees above or below the normal of the 21 years referred to above, we find a striking result. In Table X are given the day-degree departures above or below the normal for the high and low yield years. The data are represented in Chart H.

TABLE X

DAY-DEGREE DEPARTURES FOR HIGH YEAR YIELD AND LOW YIELD YEARS.
HIGH YIELD YEARS—1908, 1915, 1917 AND 1925.
LOW YIELD YEARS—1911, 1912, 1918 AND 1923.

	Month	Departures High Yield Years	Departures Low Yield Years	Normal Day-Degrees
Two years ago	May	21	3	391
	June	36	3	396
	July	25	—15	428
	August	37	—28	434
	September	39	—27	426
	October	40	—10	440
	November	18	9	402
	December	24	3	363
One year ago	January	31	— 6	307
	February	31	—11	280
	March	25	7	326
	April	27	3	339
	May	27	—13	375
	June	22	—15	378
	July	38	0	443
	August	15	12	474
	September	24	— 9	444
	October	15	—16	434
	November	24	—21	372
	December	28	—16	344
Crop year	January	16	—22	291
	February	—8	—39	252
	March	19	—46	273
	April	0	—24	312
	May	24	—25	363
	June	3	0	393
Total		591	—303	9680

It is seen that in the poor yield years the warmth has been usually less than in a normal year, and that in the good yield years the warmth has been greater.

"Critical" Periods and Crop Fluctuations

We have found that the temperature during the months of August, September and October, two years previous to a crop is of "critical" importance to the crop. Also the rainfall in the month of August, previous year, is of "critical" importance. If, as we have said, these periods leave permanent stamp on the crops, then by studying these periods it should be possible to explain the fluctuation in *yield* and even predict a coming crop.

In Table XI are given the average monthly temperature in the "critical" period mentioned above, and also the amount of rainfall in the "critical" month of August, previous year.

The temperature, rainfall and sugar yield data, are shown by three separate curves in Chart I.

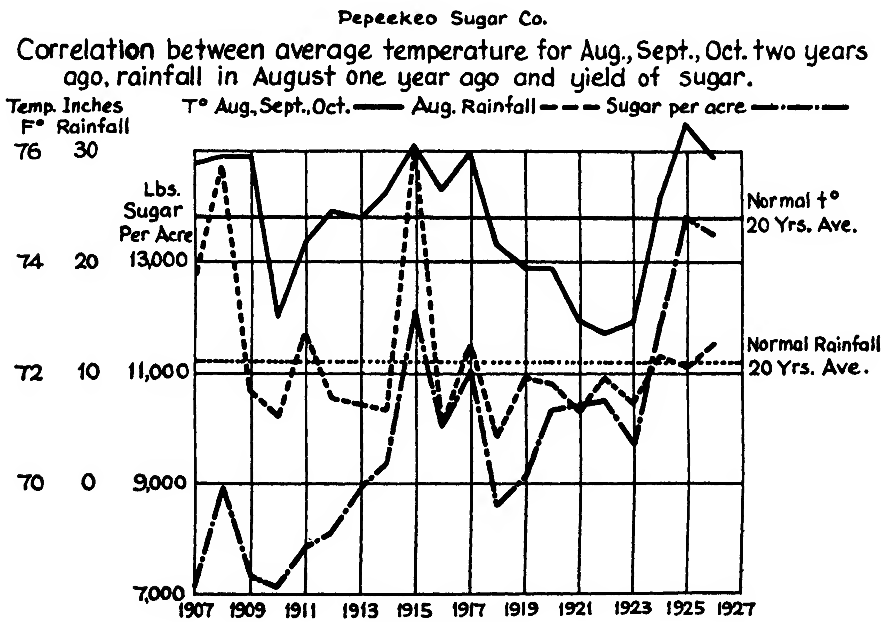


Chart I

It will be noticed that it is possible to explain the fluctuations in the sugar yields at Pepeekeo since 1906 on the basis of the weather conditions during the two "critical" periods—consisting only of four months and not the entire crop period of two years or more.

On the temperature and the rainfall curve we have shown the periodic or monthly normal by straight lines. We see that the period of low yield following 1917 had not only low temperature in the "critical" months, but also rainfall below normal in the critical month of August of the previous year.

By combining the two curves—one of critical temperature and one of critical rainfall, we may actually be able to forecast the crop at Pepeekeo a few months before the grinding starts.

TABLE XI

AVERAGE TEMPERATURE IN THE MONTHS OF AUGUST, SEPTEMBER AND OCTOBER, TWO YEARS PREVIOUS; RAINFALL IN AUGUST, ONE YEAR PREVIOUS, AND THE YIELD OF SUGAR PER ACRE

Year	Lbs. Sugar per Acre	Average Temperature Degrees August-October	Inches Rainfall in August
1907	6,977	75.8	17.43
1908	8,928	75.9	28.31
1909	7,288	75.9	8.37
1910	7,061	73.0	5.84
1911	7,762	74.3	13.59
1912	8,135	74.9	7.33
1913	8,894	74.8	7.17
1914	10,449	75.3	6.57
1915	12,094	76.1	29.75
1916	10,044	75.3	5.21
1917	11,074	76.0	12.70
1918	8,598	74.3	4.06
1919	9,069	73.9	9.57
1920	10,320	73.9	9.15
1921	10,420	72.9	6.53
1922	10,505	72.7	9.28
1923	9,650	72.9	7.10
1924	11,758	75.1	11.84
1925	13,788	76.5	10.36
1926	13,480	75.9	12.40

Recent Record Crops

The years 1924, 1925, and 1926, have all been record years in these Islands. In every one of these years, all previous crop records have been broken. At Pepeekeo, these three years, though not all record years as regards yield per acre, have been exceptionally good years.

In the light of the information obtained previously in this paper, it is possible to explain how far weather has been a contributing factor to these high yields. In Charts J and K we have plotted the average monthly temperature and monthly rainfall for the entire crop period of this group of three years. We have also plotted along with it the normal (average of 1905-1926) monthly temperature and rainfall.

It is seen from Chart J that as regards temperature the years 1924-1925, 1926, have been exceptionally favored. The temperature is higher than the normal throughout the entire crop period.

From Chart K is seen that rainfall, though not ideally distributed, has yet been favorable in the summer months, and during the ripening and harvesting season.

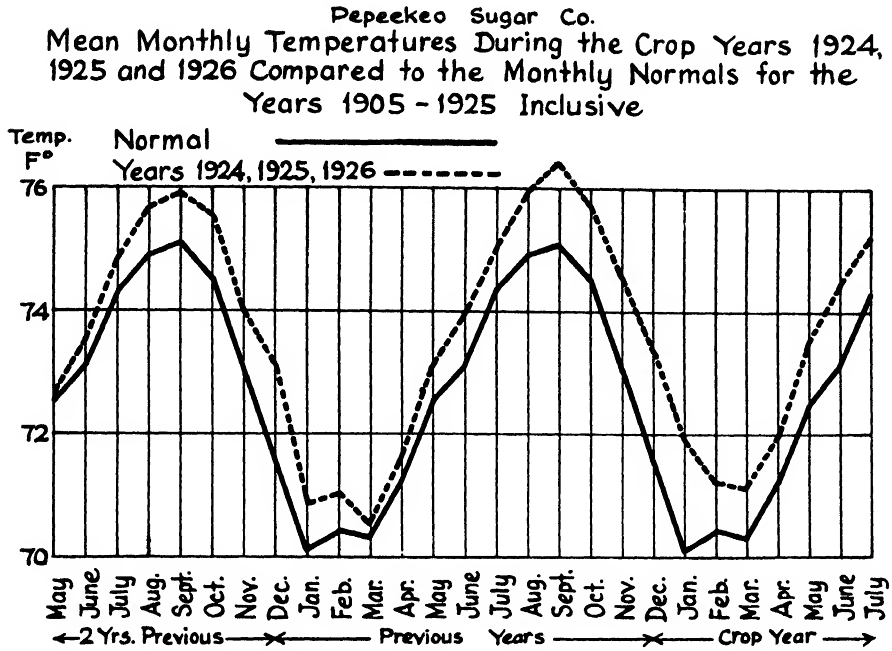


Chart J

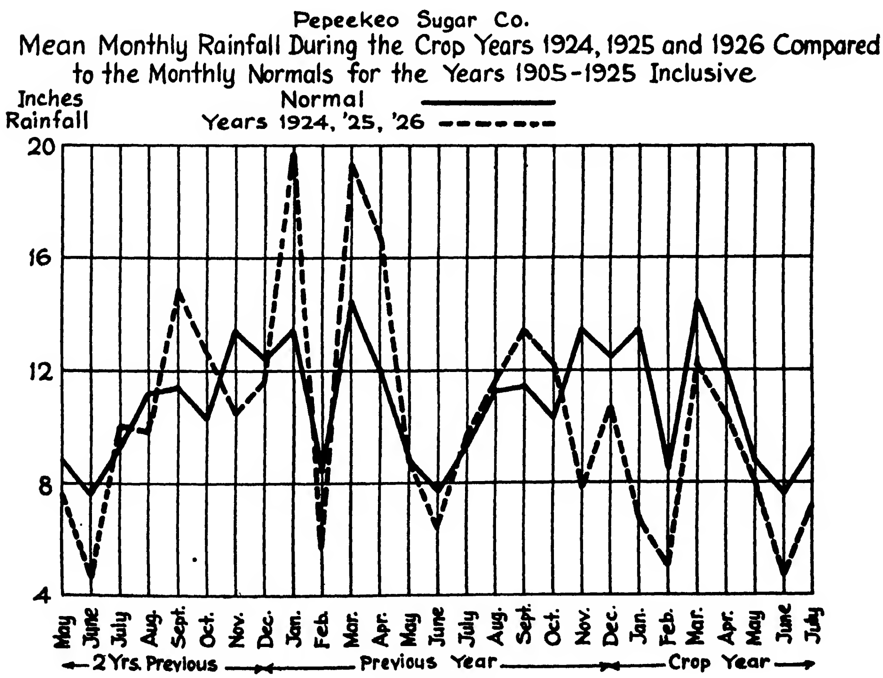


Chart K

7

Pepeekeo a Typical Unirrigated Plantation

Elsewhere we have mentioned that Pepeekeo is a typical unirrigated plantation. Chart L is brought forward in support of this contention. It is seen from this chart that there is a remarkably close relation between the fluctuations in sugar yield at Pepeekeo and at the average unirrigated plantation.

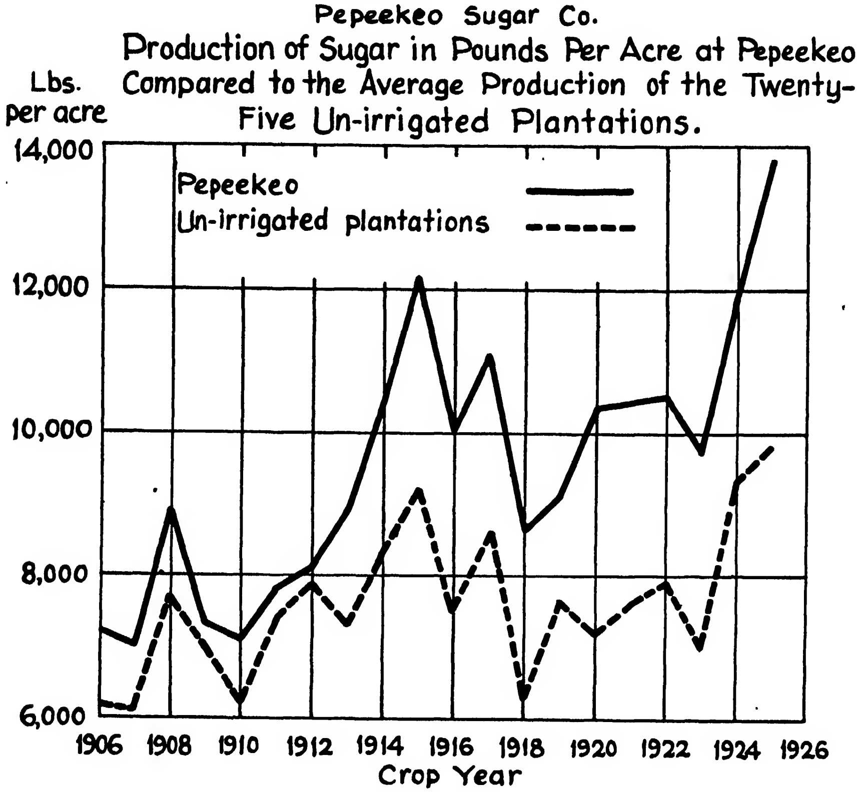


Chart L

This leads us to suggest that the conditions of weather that have been responsible for the fluctuation in yield at Pepeekeo have also been responsible for fluctuations of the same nature at other places. The unirrigated plantations, numbering 25, cultivate 49 per cent of the total area in cane in Hawaii, and produce 36 per cent of the total annual output of sugar in these Islands.

Other information of interest is brought out by Chart L. Up to the year 1912 the average production per acre at Pepeekeo is comparatively close to the average production per acre in all the unirrigated plantations. From 1912 on, the difference in the yield per acre at Pepeekeo and the average yield of all other plantations begins to increase. This increasing difference is very well brought out by the relative rise and drop of the two curves in Chart L.

The conclusion is that at Pepeekeo there have been some factors at work which have accelerated the rate of increase in the production of sugar as compared to the unirrigated plantations as a whole. In other words, Pepeekeo has progressed more since 1912 than the average unirrigated plantation.

Weather Conditions and Sugar Content of Cane

Here we have taken the figure expressing the polarization per cent cane to represent the total sugar content of cane of any crop year. Polarization per cent cane is based on the concentration of sugar in the mixed juice as well as that in the bagasse.

We propose to consider the effect of weather on the sugar content of the cane only, forgetting for the time being its influence on crop yield.

The yield of sugar depends on two factors, namely, the quantity of the cane and the quality of the cane. Of these two factors, the quantity of cane is of greater importance in most of the cases because of the fact that quantity of cane varies much more greatly than the quality of the cane.

To illustrate the point: At Pepeekeo the greatest variation in the polarization per cent in cane in any two successive years is found to be only 9 per cent between 1926 and 1927. The variation in the quantity of cane obtained is about 20 per cent between 1924 and 1925. Obviously, therefore, in most cases the yield of sugar will follow the yield of cane.

While quality is not the greatest factor in causing fluctuations, it is still of great importance.

The sugar content of cane for any one variety depends on several factors, such as:

(1) Age of cane at the time of harvesting.
(2) Season of planting and harvesting.
(3) Conditions of weather and soil during the period of growth.
(4) Cultural treatments—water, fertilizers applied, etc.
(5) Freedom from disease or other injuries.

Independently of all considerations the sugar content of cane appears to vary inversely as the quantity of cane. A year of high cane yield is likely to be a year of comparatively low sugar content in cane. In Table XII are given the yield of cane in some recent years and the sugar content in cane at Pepeekeo.

TABLE XII

Year	Tons Cane p. a.	% Increase or Decrease Over Previous Year	Polarization in Cane	% Increase or Decrease Over Previous Year
1924........	50.13	....	12.70	...
1925........	60.03	+20	12.21	—4
1926........	57.93	— 4	12.45	+2
1927........	61.84	+ 7	11.29	—9

In Chart M is shown that while the yield of sugar per acre has been progressively increasing, the sugar content of cane has been progressively decreasing. The explanation is that the increases in the yield of sugar have been obtained in spite of the decrease in the quality of juice.

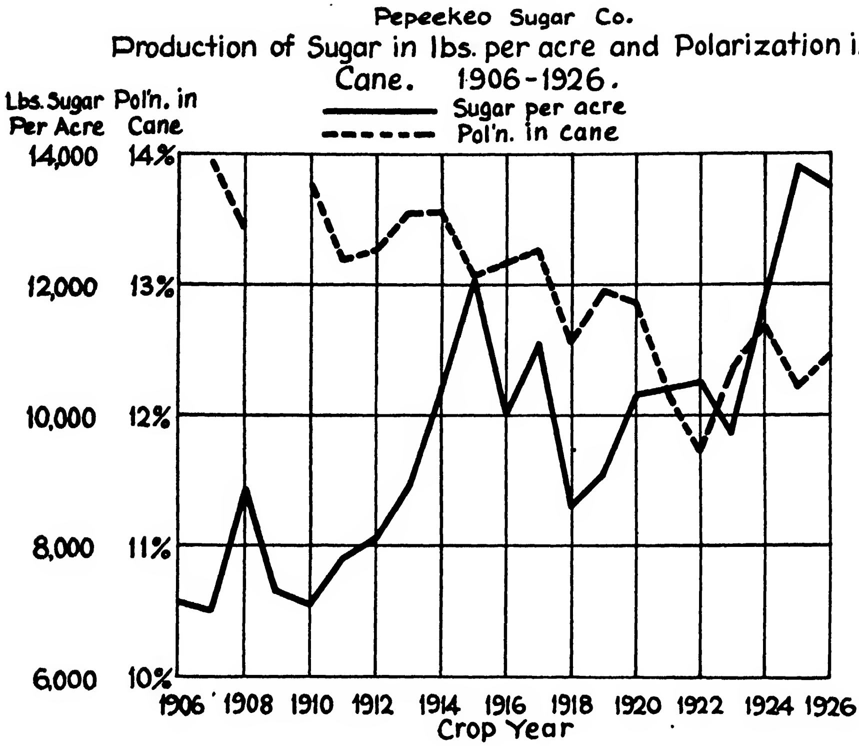


Chart M

Polarization of Cane in Different Years

In Table IV we have the polarization per cent cane for the years for which data are available. As will be seen from this table and also from Chart M, the polarization per cent cane has been decreasing progressively. In view of this, absolute comparison between two years widely separated will not be justified. We have expressed the polarization in different years as departures from a moving three-year average. Thus, to obtain the departure for 1911, we have taken the average of 1910, 1911 and 1912, and then we have calculated the departure from this average. The departures are given in Table XIII.

TABLE XIII

POLARIZATION IN CANE DEPARTURES

Year	Polarization in Cane	Three-Year Moving Average	Departures
1910	13.80	.....	.....
1911	13.21	13.41	—.20
1912	13.23	13.33	—.10
1913	13.54	13.44	+.10
1914	13.55	13.38	+.17
1915	13.05	13.26	—.21
1916	13.17	13.16	+.01
1917	13.25	13.00	+.25
1918	12.57	12.93	—.36

1919	12.97	12.80	+.17
1920	12.85	12.66	+.19
1921	12.15	12.23	—.08
1922	11.70	12.07	—.37
1923	12.37	12.26	+.11
1924	12.70	12.43	+.27
1925	12.21	12.45	—.24
1926	12.45	11.98	+.47
1927*	11.29	11.87	—.58

Formation of Sucrose

The formation and accumulation of sucrose in the cane proceeds at various stages and different rates. In the early stages of its growth, the plant goes on adding to its volume without regard to the storing of sugar. When any part is fully formed and developed then this part starts to convert the reducing sugars into sucrose and store it as such. It is believed that this rate of accumulation proceeds at varying rates. Verret and Das (5) have shown that in the case of sugar cane the rate of vegetative growth is at its maximum at five to ten months of age. There is every reason to believe that the rate of accumulation of sucrose will be at its maximum some time later. Prinsen Geerligs (6) gives the following information regarding the formation of sucrose:

	Sucrose	Glucose	Fructose
Tops of cane—6 months old	1.02	1.24	1.25
Tops of cane—9 months old	1.90	1.30	0.70
Botton joints—12 months old	16.50	0.60	0.20

It is seen from the above that accumulation of sucrose must have proceeded at a rapid rate after the ninth month, i. e., after the vegetative growth started to slow down. This is in agreement with our deductions from observing the rate of growth.

It is believed that the relationship between growth and sucrose formation is such that if growth slows down for any reason the manufacture and storage of sucrose goes on at an increased rate. Factors that help growth hinder the storage of sucrose and vice versa.

The amount of sugar stored in a cane plant will also depend on the total amount of cell space in the plant. A period of active growth, followed by a period where growth is slow, is likely to produce a high sucrose content in cane.

Temperature and Sucrose

In Table XIV and Chart N are given the co-efficient of correlation between polarization in cane, temperature and rainfall. As regards temperature there is no co-efficient of "critical" importance. But there are a few periods of interesting significance. Temperature is seen to have a negative correlation in some of the

* 1927—Calculated from two-year average.

Pepeekeo Sugar Co.
Co-efficients of correlation between Rainfall, Temperature and Polarization in Cane (1911-1927).

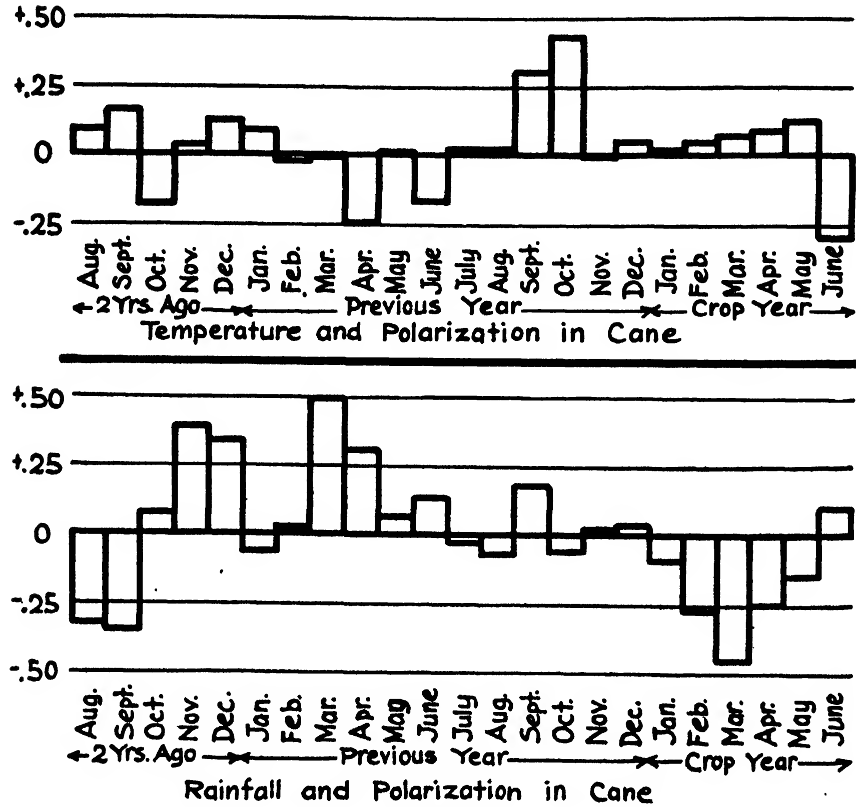


Chart N

earlier months, and a positive correlation with sucrose during the final stages of the crop; that is, high temperature during the earlier months is not helpful to sucrose formation, but during the later period it is.

High temperature during the earlier stages helps vegetative growth and probably, because of this very reason, hinders the storage of sucrose. It is possible that with certain exceptions, and limitations, high temperature during the ripening period actually increases the concentration of sucrose by evaporating the surplus water in the cane.

Rainfall and Sucrose

Though there is no period of "critical" importance, yet there are two periods which are almost so. These are the months of March of the crop year and of the previous year. There are also two other periods of very great significance in that a series of succeeding months seem to have the same helpful or harmful effect. These are the months of February to June, inclusive, of the previous year, and the months of January to May, inclusive, of the crop year. The first period of

five months, and including the near-critical month of March, is positively correlated with the storage of sugar, while the second period of five months, including the near-critical month of March, bears a negative correlation to polarization in cane.

As we have seen before, the month of March is usually the wettest month of the year. A very wet March in the year previous to the crop year, coming at a time when the cane is young, is likely to slow down growth, especially because of the prevalence of very low temperature in this month. The rainfall in this month is seen to have a negative correlation with crop yield, which, in view of the fact that it has a positive correlation with polarization, would seem to suggest that negative crop yield at this period must have been brought about by lowered yield of cane tonnage.

TABLE XIV

CO-EFFICIENTS OF CORRELATION BETWEEN TEMPERATURE, RAINFALL AND POLARIZATION IN CANE

(1911—1927)

		Rainfall and Polarization	Temperature and Polarization
Two years ago	August	—.23	.09
	September	—.25	.16
	October	.08	—.19
	November	.39	.03
	December	.34	.12
One year ago	January	—.06	.09
	February	.07	—.03
	March	.49	—.01
	April	.30	—.25
	May	.06	.01
	June	.13	—.18
	July	—.03	.01
	August	—.07	.01
	September	.17	.30
	October	—.06	.43
	November	.02	—.01
	December	.03	.05
Crop year	January	—.09	.01
	February	—.28	.05
	March	—.46	.07
	April	—.25	.09
	May	—.15	.12
	June	.10	—.31

It is, therefore, reasonable to believe that high rainfall in March of the previous year, coupled with the usual low temperature, slows growth considerably, and probably helps storage of sugar for this very reason.

There is also another consideration that is of significance. As has been shown by Prinsen Geerligs (6), the rate of sugar manufacture proceeds at a rapid rate in that region of a cane plant which has stopped to grow actively, which will be at about 12 months of age.

In the month of March, a year previous to the crop year, most of the cane is at the age when rapid accumulation of sucrose is taking place. This rate is, no doubt, further accelerated by the slowed growth process.

The same considerations, perhaps, apply to the whole period of five months from February to June of the previous year.

The harmful effect of high rainfall in the ripening and grinding season is everywhere recognized. High rainfall at the last stages causes harm because of several reasons: (1) it dilutes the juices and lowers the percentage of polarization; (2) it may, coupled with other factors, break down a part of the sucrose into other sugars; (3) it may help start new lateral shoots which will draw on the stored sucrose in the cane.

It is seen that at Pepeekeo rainfall is of greater significance than temperature in regard to the polarization in cane. It is not, however, suggested that the same will hold true in every place. We believe that both temperature and rainfall have a great bearing on the sucrose content of the cane. In other words, we may say that sucrose per cent in cane depends, among others, on two important factors, namely, temperature and rainfall. Of these two variables, the one that varies to a greater extent than the other will exert greater influence. If in any locality the range of temperature variation is comparatively greater than rainfall variation, then we may expect that sucrose content will vary more in accordance with temperature than with rainfall. The opposite will hold true in cases where rainfall variation is greater.

"Active" Rainfall and Polarization

We have seen that as regards the effect of rainfall on sucrose content we have two periods of significance. One period consists of five months from February to June, one year previous to the crop year, and the other of five months from January to May of the crop year. Both periods are of equal duration, and it appears that both periods have just about the same importance. The first period has positive correlation, and the second one a negative correlation to sucrose content. If we ignore for the time being the effects of rainfall in the other months and also the effect of temperature, then we can say that fluctuations in the polarization per cent cane from year to year are brought about by the resultant activity of these two periods.

To express in a simple manner the resultant effects of these two periods, we have used a term "active" inches of rainfall. The "active" inches of rainfall in regard to any crop year are obtained in the following manner: We will assume that rainfall in the first period makes or helps to make sucrose in cane, and that high rainfall in the second period tends to destroy the sucrose already formed. We will take, then, that the difference in rainfall between the first and the second period, added or subtracted from the first period, will give us the amount of "active" rainfall. If the first period has more rainfall than the second period, then the result will be so many inches difference in rainfall in favor of the first period, and exerting a proportionate influence in the same direction. If the second

period has more rainfall than the first, then the result will be the difference which will counteract the good influence of the first period.

To illustrate: The first period has a rainfall of 50 inches, and the second period 60 inches. "Active" rainfall will be 50″—(60″—50″) or 40″.

Again, if the first has a rainfall of 50 inches and the second 40 inches, then the "active" rainfall will be 50″ + (50″—40″) or 60″.

In other words, if the second period has more rainfall than the first, it helps to decrease, and if it has less rainfall, it helps to increase the amount of sucrose already formed.

In Table XV we give the "polarization" in cane for different years and the "active" rainfall in the related period. The data are shown graphically in Chart O.

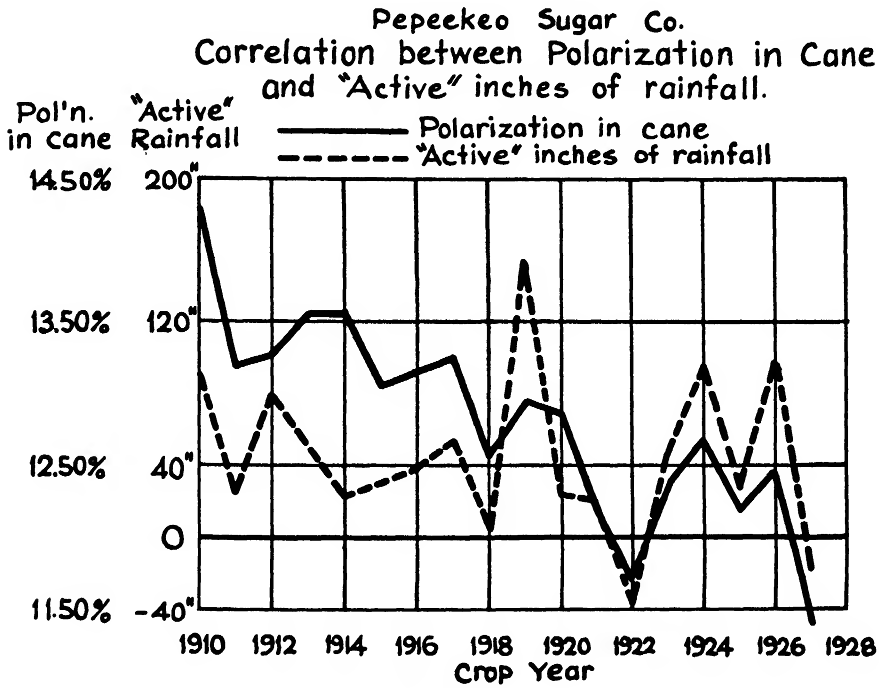


Chart O

From Chart O we see that the fluctuations of polarization per cent cane from year to year show a remarkable relation to the fluctuations in the amounts of "active" rainfall from year to year.

It therefore follows that the sugar per cent in cane does not depend entirely on the conditions prevailing during the grinding and ripening season, but depends almost as much on the weather conditions in a previous period.

1927—Low Polarization in Cane

The year 1927 has been the poorest year from the point of polarization in cane. In the light of what has been said before we are in a position to explain the cause of such poor juices at Pepeekeo this year.

In the months of February to June of 1926 rainfall amounted to only 20.51 inches, while in the five months period of January to May, 1927, the amount was 56.88 inches—"active rainfall" was, —17 inches. This has no doubt been a great factor in determining the quality of juice.

TABLE XV

"ACTIVE" INCHES OF RAINFALL AND POLARIZATION IN CANE AT PEPEEKEO

Year	Polarization in Cane	Inches Rainfall Feb.-June Previous Year	Inches Rainfall Jan.-May Crop Year	"Active" Rainfall (in Whole Numbers)
1910	13.80	65.90	38.72	92
1911	13.21	45.72	68.08	24
1912	13.23	63.45	45.66	80
1913	13.54	53.52	61.11	47
1914	13.55	37.11	53.22	21
1915	13.05	60.66	38.35	84
1916	13.17	45.08	52.70	37
1917	13.25	50.45	46.28	54
1918	12.57	53.46	103.65	2
1919	12.97	93.29	32.20	154
1920	12.85	32.78	40.73	25
1921	12.15	38.74	58.51	19
1922	11.70	29.48	95.97	—38
1923	12.37	74.91	105.60	43
1924	12.70	70.32	45.08	95
1925	12.21	44.16	59.94	28
1926	12.45	56.34	22.06	100
1927	11.29*	20.51	56.88	—17

It is also seen from the weather records that in the grinding and ripening season of the 1927 crop, average monthly temperature was a few degrees higher than the normal; rainfall in the same period was abundant and well distributed. The combined effect of temperature and rainfall was, no doubt, calculated to produce new vegetative growth. This new growth reduced the already meagre store of sucrose. A combination of factors—not one factor—has been responsible for such poor quality of juices.

Though it does not have any direct bearing on Pepeekeo, still it may not be out of place to refer to a report of R. H. McLennan. Writing from Grove Farm, Kauai, on September 23, he says that a field of U. D. 1, harvested in the middle of September, contained from 45 per cent to 50 per cent suckers in the cane sent to the mill.

Knowing that millable cane does not start to form before the cane is about six months old, we can easily trace that most of the suckers must have started to grow in the winter months—December to March.

* Figure up to end of August only.

Well distributed rainfall and high temperature during the ripening and harvesting season has been a marked phenomenon in most of the plantations in these Islands. Pepeekeo had the same conditions as Grove Farm Company. It is not, therefore, unreasonable to assume that at Pepeekeo also a substantial percentage of the crop harvested this year included cane of tender age and very little sucrose.

Conclusions

(1) A study of weather conditions at Pepeekeo—namely, of temperature and rainfall—reveals that these have contributed to a large extent to the yield of sugar per acre from year to year.

(2) At Pepeekeo the mean temperature during the months of August, September and October, two years previous to a crop, and rainfall in the month of August, one year previous to a crop, appear to exert very great influence on the yield of sugar per acre in that crop year.

(3) Independently of other considerations, polarization in cane appears to be greatly influenced by the rainfall in two periods. The first period includes February to June of the year previous, and the second period January to May of the crop year. High rainfall in the first period tends to help or increase the formation of sucrose, and that in the second period tends to decrease the amount of sucrose already formed.

Literature Cited

(1) Jorgensen, J. P.—Rainfall of St. Croix in relation to sugar crops. Reprinted in *West Indian Bulletin*, Vol. VII, p. 260, 1906.

(2) Koenig, M.—Critical periods in the growth of the sugar crop. Bull. 27, Department of Agriculture, Mauritius. 1923.

(3) Tengwall, T. A., and Van Der Zyl, C. E.—Het verband tusschen klimaat en suikerproduct op Java in Archief voor de Suikerindustrie in Nederlandsch-Indie, XXXII, Deel 3, 1924.

(4) MacDonald, W. F.—Weather and sugar cane in Louisiana—in *The Planter and Sugar Manufacturer*—May 29-July 17, 1926.

(5) Verret, J. A., and Das, U. K.—Rate of cane growth at various ages—in *The Hawaiian Planters' Record*, Vol. XXXI, No. 4, p. 314, 1927.

(6) Geerligs, H. C. P.—Cane sugar and its manufacture (second edition), p. 92, published by Norman Rodger, 1924.

Notes on *Pythium* Root Rot of Sugar Cane

By C. W. Carpenter

These notes discuss various phases of *Pythium* root rot for the purpose of giving those following our work an outline of some things we are trying to do, and do not represent an attempt to write a scientific treatise on the results of complete investigations.

Recently, investigators of root rot of cane in Hawaii have come to consider the disease a complex of some half dozen factors, of which parasitic fungi is but one. The subject of the writer's previous investigations was the root failure and crop failure of the type we were observing in certain areas on Oahu, specifically with Lahaina cane in the Waipio and Waipahu district. It was concluded then that a species of *Pythium* was the primary cause. Several other factors concerned in root rot while observed, were not investigated at that time, and some of these are now appropriately being studied in the departments of entomology and chemistry.

Lahaina Disease and the Root Disease Complex

In extending the researches on the general problem of root disease under the conception of the root disease complex*, the following factors have been included under cooperative investigations between the departments of chemistry, entomology and pathology: 1. Aluminum and ferrous iron toxicity of the soil. 2. Unfavorably high concentrations of mineral salts in the soil. 3. Nematodes of the genus *Heterodera* attacking the cane roots. 4. Nematodes of the genus *Tylenchus* attacking the roots. 5. The effect of unfavorable ratios of replaceable bases. 6. The effect of Isotomodes and other small soil-inhabiting fauna. 7. Fungous root rots.

The variety Lahaina continues to be largely used for root disease studies. It has been stated several times, and may well be emphasized here, that in seeking to find the causes of the root diseases of Lahaina cane, we are not trying to restore this variety to commercial prominence. We are using this susceptible variety rather as a key to the combination of root failure in general.

The failure of the Lahaina variety throughout the sugar cane countries of the world could not logically be attributed to combinations of factors unless we are ready to admit that vegetatively propagated plants deteriorate *per se*. We must logically seek one factor or a small series of related factors,—fungous root parasites, for example, as the primary cause of this extensive growth failure. First in one country and then in another, cane planters' experiences repeated themselves with this variety. Commercially it scarcely exists today. And still this variety does not appear to be vegetatively weakened. It will grow well in many soils virgin to cane.

Old ratoons continued to yield well according to the experiences of some of our planters, but when plowed out and replanted to Lahaina the results were disappointing. This seems to be the result of a balanced relation between the large root system of the ratoon and the root disease; when the cane is replanted, very few roots starting out have to contend with an accumulation of root organisms nourished by the old stool. A resistant variety, while being attacked to some extent, is able to produce root area faster than it can be destroyed by the root disease.

Can it be that the unfavorable factors of physical and chemical composition of cane soils were so generally distributed and so suddenly became primary

* Agee, H. P. In Reports of the Association of Hawaiian Sugar Technologists, 1926, pp. 5-10.

factors in the succeeding epidemics of root disease of Lahaina in the cane countries of the world? Entire plantations had to be replanted to other varieties in two or three years. It seems more probable that living parasites of the roots are the primary factors in such recurrent outbreaks. The non-living factors conceivably are often but predisposing causes; often they are independent in their action, and more or less localized in their distribution. They are not epidemic in nature, though often able to spread or seem to spread in their effects in more or less contiguous areas where soil conditions are similar, agricultural and fertilization practices uniform, water supplies of like character, etc. Neither combinations of such factors nor any one of them would we expect to similarly devastate a variety of cane on the diverse cane soils, and under the varied agricultural practices of cane culture of the world, still permitting commercial culture of closely related strains. This sort of disease resistance seems to be identical with resistance to a fungous parasite. Steam or formalin sterilization of sick soils likewise permits of normal growth of this variety in pot cultures.

We should not minimize the harmful effect of: (1), any unfavorable chemical and physical factors of the soil that we find to apply to the various commercial varieties in different degree in Hawaii, and (2), variability in degree of compactness of the soil, stagnation of soil water, etc., as the Java writers state to be the cause of root disease of cane under their conditions. It seems more logical for a universally active disease such as root rot of the Lahaina variety, to consider living parasites primarily responsible.

The other factors do cause retarded growth and growth failure in Hawaii, the extent of which is being determined by the departments concerned. That they are universally active is not claimed by those studying these aspects of the problem. The interrelations of the physical and chemical soil environment and the living parasites of the roots remain largely to be determined.

After the role of the various living factors prejudicial to normal root development of present standard canes has been more completely investigated, we will have some idea of how much damage they are causing.

This broader conception, taking in all known factors in root failure, under the general project "root disease complex," is an advance in root studies, which means progress, not only in the investigation of the specific type of disease referred to above, but in all cane root failures, since a cooperative study by workers in several departments was the natural outgrowth of this broadened viewpoint.

Pathological Considerations

Of the cane root inhabiting fungi in Hawaii, a species of *Pythium**, described by the writer as morphologically identical with *Pythium butleri* Subramaniam and *Rheosporangium aphanidermatus* Edson, now perhaps more appropriately referred to as *Pythium aphanidermatum* (Edson) Fitzpatrick†, is the only one of demonstrated parasitic habit. The vast number of species of bacteria and fungi other than *Pythium aphanidermatum*, which, at times, may also be found in and

* Bull. of the Exp. Sta., H. S. P. A., Bot. Ser., Vol. III, Part 1, p. 64, 1921.

† Fitzpatrick, H. M. *Mycologia* 15, p. 166, 1923.

about cane roots, remain to be considered. Similarly the other biological factors have scarcely been touched. It is believed that the most logical method to approach a solution of the root failure problem, as it applies to our present standard varieties, is by gaining thorough knowledge of the factors concerned. While methods of control may be enthusiastically studied where there seems to be a basis for a theory, the results of our study promise most success if the factors involved are taken up and understood a few at a time. In this department we are attempting to learn more about the nature of *Pythium aphanidermatum* and related forms, and any other fungous or bacterial inhabitants of the roots, together with the relations of any parasitic forms to: (1), the cane plant; (2), the physical and chemical composition of the soil; (3), to other root parasites; (4), to the biological population of the soil; and (5), to chemical antiseptics and disinfectants. As to the possibilities of the last-mentioned as a means of control, we maintain a conservative outlook, since this means the discovery of a substance which will destroy or restrict one form of life in the living soil, and yet be practically harmless to the cane roots as well as the beneficial organisms of the soil.

As opportunity permits we plan to make some physiological and histological studies pertinent in their bearing on the life history of the organisms and disease resistance. We expect the growth failure investigation to benefit largely by the close cooperation between the several departments concerned.

Occurrence of *Pythium aphanidermatum* in Hawaii

In the course of our investigations in various localities of the four Islands where cane is grown, we have a record of this fungus on the cane varieties mentioned below.

Lahaina, E. K. 28, H 146, D 1135, Yellow Caledonia, H 109, Porto Rico Uba, Kassoer, Natal Uba, 20-S-20, P. O. J. 213, and P. O. J. 36.

A related form of *Pythium* or possibly *Aphanomyces*, with a rough walled oospore, first observed on H 109 at Wailuku in 1920, has been seen in association with diseased roots of Lahaina cane at Olaa, Onomea, Pepeekeo, and Honokaa, on Hawaii, and on H 109 at Olowalu, Maui.

E. K. 28: We are of the opinion that the variety E. K. 28, recently introduced into our Makiki and Alexander Street experimental plots, will prove unsatisfactory where *Pythium* root rot is a factor. At the Makiki plots this variety is very promising and shows no indications of weakness arising from the existing soil conditions; but at Alexander Street, where we have some history of root rot in other varieties, E. K. 28 is an unqualified failure.

Examinations of the roots of moderately diseased plants, as well as those almost dead, revealed the *Pythium* fungus in abundance, and it was the only parasitic type of fungus isolated. Nematodes are not an important factor here and the condition of the soil appears most favorable. Pure cultures from these isolations are now considered to be *Pythium aphanidermatum.*

The variety E. K. 28 has a root rot history in Java. Regarding this variety Lyon* writes as follows:

In recent years a seedling cane known as E. K. 28 has become the leading cane variety in Java, and now occupies fully 40 per cent of the total cane growing area of the island. This seedling is very subject to root rot, however, and in 1921 the disease became so prevalent in E. K. 28 that some expressed fears that the variety would be eliminated altogether. This scare caused many growers to turn from E. K. 28 to other more resistant varieties in their plantings for the 1922 crop.

Dr. Kuyper's description of root rot in Java tallies very closely with the symptoms of the disease as displayed by Lahaina cane in Hawaii. He asserts that the malady occurs in practically all the cane varieties of Java.

It may be said that Dr. Kuyper, according to Lyon's resumé of his work, while offering no proof of his theories, is nevertheless confident in his statements. According to him the disease is caused by a lack of oxygen, a temporary or constant anaeroby, as for instance, in a soil supersaturated with standing water and, therefore, low in oxygen, etc. His contentions should not be difficult to prove if they are correct.

We know that cane is rather tolerant to fluctuations in the ration of water. A soil organism like *Pythium,* which requires water for growth and for the dissemination of its zoospores, would be a stronger factor in root rot when there is sufficient water for these purposes. With sufficient water it can spread rapidly and seriously rot the roots in a few days, and when the plant symptoms show above ground, as I have previously pointed out†, it is too late to find the organism in abundance. The conception I favor now is that *Pythium* root rot is comparable in its rapid attack, and the transitory period thereof, with the *Phytophthora* blight of potato tops. When the conditions are right the damage is done in a very short period, and several days or weeks later is not an opportune time to look for the parasite. With *Pythium* root rot the half-dead plants are not as suitable material for observing and isolating the causal organism as the seemingly healthy plants close by the diseased area. Here it is often working in a moderate way, alive and active, awaiting more favorable conditions for the next outbreak.

It seems more reasonable to suppose that the cause of a serious root rot like this is favored by water rather than to assume from circumstantial evidence that either excess or deficient water in combination with various soil conditions has swept Java with a root rot scourge, and by inference, the cane countries of the world under all types of soil, selecting primarily the Lahaina type.

The writer agrees with Lyon that while Dr. Kuyper's explanation may seem sufficient to those familiar with the disease in Java only, it certainly will not convince those studying root rot elsewhere.

In this connection some recent observations at the new substation at Kailua, Oahu, are rather significant.

At Kailua, where Lahaina cane together with H 109 was planted in January, 1927, in former rice patches, the former variety is growing at a rate comparable with the latter and shows no signs of distress. A stool was recently removed and

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* *Hawaiian Planters' Record,* Vol. XXVII, p. 259. 1923.

† Bull. of the Exp. Sta., H. S. P. A. Bot. Ser. Vol. III, Part 1, p. 62, 1921. See also *Hawaiian Planters' Record,* Vol. XXIII, No. 3, pp. 155-159, 1920.

the root system examined. It was one of the best root systems we have ever seen. Not a single spot or flaw suggestive of root injury could be found.

Young Lahaina cane located near by in the same type of soil is beginning to show distress of scattered stools. Such plants removed and examined revealed on the roots of a stunted stool, lesions typical of *Pythium* root rot, and on the roots of a healthy plant about ten feet away, no sign of *Pythium* could be found. The fungus was isolated in pure culture from the roots of the stunted cane.

This field is a recently acquired rice patch of the heaviest soil, shallow, poorly drained, soggy, and with a puddled subsoil of a rubber-like consistency. If the theories advanced in Java as to the nature of the soil itself being the cause of root rot were correct, we should not expect to be able to grow a stick of cane under these extreme conditions. Of course this area is being drained and improved, but the larger Lahaina mentioned was planted in midwinter, and the succeeding six months before adequate drainage could be provided, was a period of unusually heavy rainfall reaching freshet proportions at times. The evidence here supports the view that *Pythium* is just getting established, and we await further developments with interest.

H 109: On the standard variety H 109, *Pythium aphanidermatum* is occasionally found. Where small areas of this variety suffer from growth failure, and *Pythium* is present, it does not appear to be present in sufficient amount to be the primary factor involved. Where *Pythium* has occurred on H 109 in an alarming amount it has subsequently been demonstrated in some instances that there was a definite deficiency in soil nutrients or an unfavorable soil composition. Apparently *Pythium* does not occur with greater frequency nor does it do more damage on H 109 than it did seven years ago. At that time it was stated that the resistance of H 109, D 1135 and Yellow Caledonia was relative and not absolute.

Relation of *Pythium aphanidermatum* to Nematodes

In cooperative studies with R. H. Van Zwaluwenburg we have not observed any support for the view that the punctures of nematodes furnish the entrance channel for *Pythium aphanidermatum*. This view may be true for some of the less aggressive fungi and wound parasites, but in general there seems to be no intimate association of nematodes and *Pythium*. This latter is capable of entering the roots freely, both cortex and stele, in sterilized soil inoculated with the fungus in pure culture. Nematodes and *Pythium* do occur often on the same root systems, but we have observed no interdependence in their relations. *Pythium aphanidermatum* on the contrary seems to prefer a healthy root for its nourishment.

Relation to Soil Reaction

Preliminary experiments have determined the fact that one strain of *Pythium aphanidermatum* when cultured on a buffered nutrient medium can grow over a range of hydrogen ion concentrations comparable with those exhibited by most of our sugar cane soils. This suggests that adjustment of soil reaction is not feasible as a means of control.

Relation of Temperature and Moisture

We have almost no experimental data in regard to the relation of *Pythium aphanidermatum* to temperature and moisture factors. In this equable climate we would expect very slight variations of soil temperatures between day and night, the only changes to be expected would be the slightly-lower soil temperatures of seasonal variation in the winter months. Any effect of temperature in relation to root disease seemingly is a result of rate of growth on the part of the plant rather than a direct reaction on the fungus. Slower root development allows the parasite to destroy root area faster than it is replaced.

Essentially the *Pythiaceae* are water fungi, though some forms have taken to a terrestrial life. This group is dependent on moisture for completing the asexual or zoospore stage, but *Pythium aphanidermatum* grows less actively in the vegetative stage in deep liquid cultures than on agar surfaces, indicating a preference for a solid substratum for vegetative growth or a semi-aquatic type of life-cycle.

Sufficient moisture for good growing conditions of the cane plant offers sufficient moisture for the purely vegetative processes of the fungus in getting from one root to another. With occasionally increased supplies of soil water the zoospore stage offers a means of wider dissemination.

Notes on Root Rot on the Island of Hawaii

A trip was made to Hawaii, August 16-22, to inspect the Lahaina plantings made in cooperation with the Olaa Sugar Company, Ltd., Honokaa Sugar Company, Onomea Sugar Company, and Pepeekeo Sugar Company. The object of this cooperative planting of Lahaina cane where it failed many years ago (1896 and on), was to find how this variety would grow now, and if it suffered from growth failure, to find if possible the nature of the causal factors.

The cause of the growth failure of Lahaina in the Hamakua and Hilo districts in the closing years of the last century has long been a subject of interest. The first inspection of the Lahaina plantings, reported in detail herein, revealed in every plot a more or less active "root rot" of the sort we have associated with invasion of the roots by fungi of the genus *Pythium*. The presence of *Pythium* species in the roots of the Lahaina in all four localities and at several elevations from 100 to 1250 feet considered in relation to our previous experiments with this type of fungus supports the view that *Pythium* species were a very important factor in the serious growth failure of Lahaina in former years.

Further inspection at intervals of a few months are expected to prove helpful in advancing our knowledge of growth failure. Through the cooperation of the chemistry and entomology departments, representatives of which join in the inspections, progress is anticipated in determining the relation of *Pythium* and nematode species as causal factors in root failure and in revealing something as to the nature of the environmental soil factors involved.

Observations made on this trip are first reported by the plantation, followed by a summary of preliminary data. Seed was furnished in each case by the Experiment Station, H. S. P. A. Data as to area, elevation, planting dates and fertilization of the respective plots are incomplete, but this will be furnished us later and incorporated in subsequent reports.

OLAA SUGAR COMPANY, LIMITED
Field "W", Sec. "B" of Sec. 1
Area, about 1/20 acre
Planted, May 20, 1927
Elevation, about 1000 feet

The Lahaina was about two and one-half to three feet high and had made a fair germination; growth compared favorably with the adjoining D 1135 which is about one week older. The cane was not as vigorous or healthy in appearance as the Lahaina in Field J-2 of this plantation, largely due perhaps to climatic and soil differences. Three plants were removed, the root systems exposed by washing and specimen roots preserved for later observation.

All plants examined had poor root systems with a considerable number of roots showing red cankered spots, red cankered girdling areas and flaccid root tips. Even the young primary roots issuing from the base of the young shoots were similarly affected. Forced branching was common, following rot of the tip of the primaries.

Microscopical observations: Typical spores of *Pythium aphanidermatum* were found in quantity in some of the diseased roots. Typical *Pythium* type mycelium was seen in interior cells and surface cells in close association with the red cankered areas. Several roots had the tip cut off by deep, girdling, red cankers, with the soft tips containing *Pythium* spores and mycelial hyphae.

A few brownish spores with rough walls, in contrast to the smooth wall of *Pythium aphanidermatum,* were noted in this material. My earlier notes record similar oospores in association with root rot of H 109, February 12, 1920, in Field 49, of the Wailuku Sugar Company, where *Pythium aphanidermatum* was active. This is an associated form necessitating further investigation, and is possibly another *Pythium* or a member of a closely related group such as *Aphanomyces.*

D 1135: A young stool of D 1135 in an adjoining field was examined for root conditions. On the roots a few red cankered lesions were detected. However, upon later examination, no significant facts were observed.

Field J-2
Area, 1/20 acre
Planted, May 20, 1927
Elevation, about 300 feet

The Lahaina cane showed a better growth here than in Field W, Sec. B of Sec. 1 of Mountain View, and though it had germinated well, the plants in general were rather small compared with the near by Yellow Caledonia. The plants were about two and one-half to three feet high, and smaller than the Yellow Caledonia by about one-third.

Several plants were removed and the root systems washed out. Poor root systems were the rule. Few live roots were seen except the very youngest. There was a noticeable lack of fibrous roots; flaccid root tips and forced branching of the primaries were common even in the comparatively vigorous appearing plants; the young roots, too, were often flaccid.

Microscopical observations of the softened roots showed numerous spores of *Pythium aphanidermatum.* In addition, associated with some roots, mostly externally, were the rough-walled *Pythium* type spores mentioned above in Field W, Sec. B. They were yellowish-brown in color and, roughly, twice the diameter of the spores of *P. aphanidermatum,* though the interior spore itself exclusive of the rough appendage was approximately the same size.

Some large roots showed only hyphae of *Pythium aphanidermatum* type in the cells, though determinations in such preserved material are often unsatisfactory.

HONOKAA SUGAR COMPANY
Field 29
Area, about one-half acre
Planted, April 18, 1927
Elevation, about 500 feet

This Lahaina was planted in a field where H 109 did rather poorly. Adjoining the Lahaina plot now are D 1135, P. O. J. 36 and 213.

The Lahaina had germinated poorly, but growth compared well with adjoining cane. Some seed pieces were just sprouting, and on some the band roots had not started, or, if so, only on one side of the set. Several plants were removed and examined. The roots of the larger plants were in good condition, not having many lesions, while those of the smaller plants had poor root systems. Observations later revealed numerous typical oospores of *Pythium aphanidermatum,* and it was concluded that *Pythium* root rot was present though not in as active a state as sometimes seen.

H 109: Some of this variety which was growing across the road and pipe line from the Lahaina plot was doing poorly and was being replanted. Examination in the gross and microscopically revealed no *Pythium.*

Field No. 6
Area, about one-half acre
Elevation, about 1250 feet

The first lot of Lahaina seed germinated poorly and after two or three weeks replants were made with a second lot. The stand was uneven with two series of plantings, but discounting for this, the Lahaina was not as vigorous as that in the lower field (Field 29). Roots examined from plants of both sizes showed a restricted development with soft, flaccid tips, characteristic of the *Pythium* type of rot. Microscopical observation later showed the *Pythium* type mycelium packed in the cells, but pre-sporangia or other definite criteria of *Pythium aphanidermatum* were not found. Of interest was the occurrence in abundance here also of the rough-walled *Pythium* oospores mentioned above, in the soft and decayed roots.

ONOMEA SUGAR COMPANY
Field 33
Elevation, about 1200 feet

Although Mr. Moir took especial care of his allotment of Lahaina seed, this upper field was in decided contrast to the good, even stand in the plot in Field

34. This upper field showed a poor stand, with scattered, rather pale-looking plants, compared with Yellow Caledonia and D 1135 adjoining. This is a cool, wet location on the flat top of a mountain ridge.

Several small and large plants were dug, washed and examined. The seed or band roots were rotted off already, and scarcely a healthy appearing root was found. New primary roots originating on the base of the shoots were badly red cankered, watery translucent to yellowish in appearance. There were no fibrous roots. This Lahaina was in a precarious condition already, and if existing conditions persist, little growth can be expected.

Microscopical observations: Oospores of *Pythium aphanidermatum* were present in the reddened and yellowish water-soaked root areas of large, short, young roots arising from the base of the stalk. This appeared typical *Pythium* root rot at date of observation.

Field 34
Elevation, about 400 feet
Mud press, 15 tons per acre, was spread before planting

Here the Lahaina was growing in a good, even stand, as a result of good germination. Unusual precautions were taken by Mr. Moir to insure a good start for both these experimental plantings at Onomea. The plants were about four feet in height.

Average plants, as well as large and small plants from various parts of the plot, all had developed a fairly good root system, but this was now breaking down badly. The older roots were rotted and blackened, while the new primaries from the stalk base were badly cankered with red spots of infection, and had a general water-soaked, translucent, yellowish to red appearance, with flaccid tips rather common.

Only one of the plants examined had any noticeable recent development of fibrous roots on the older primaries, the latter being now badly rotted and almost severed from the plant. The newest shoot roots, about three to four inches long, were rotted the whole length before any secondaries had a chance to develop.

Apparently this Lahaina made a good start and grew well until recently, when the conditions favored root rot. The whole root system, old as well as new roots, was breaking down. It may be noted that this soil is in an excellent state of tilth, being deep and easy to work.

Microscopical observations: Oospores of *Pythium aphanidermatum* as well as pre-sporangia of this fungus were found, but not in the abundance I anticipated from the typical appearance of the rot and the degree of development. However, once more the presence of an associated *Pythium*-like fungus with rough-walled oospores was observed, as noted previously at Olaa, Honokaa, and later at Pepeekeo. From some unpreserved material from this field at Onomea an attempt is being made to isolate one or both *Pythium* types.

Yellow Caledonia: Adjoining the Lahaina is Yellow Caledonia. A small plant was dug up and examined. Root lesions, though not common, were found. Examination later showed the new rough-walled *Pythium* present in great amount, in association with the rotting tips.

PEPEEKEO SUGAR COMPANY
Field 1
Elevation, about 100 feet

A rather uneven stand of Lahaina characterized this plot. The root system was fair, the new roots appeared healthy, and without the reddish lesions readily found in most of the other plots visited. Closer examination, however, revealed that the older roots as well as some younger primaries were discolored and flaccid. Many soft, flaccid roots from the base of the shoots indicated a period of rotting preceding our visit, but changed conditions appeared to have recently brought about a normal development. At this time *Pythium* root rot was not in an active phase.

Microscopical observation: *Pythium aphanidermatum* oospores were observed, but only in small numbers. Large numbers of the above-mentioned rough-walled oospores were found associated with the root rot.

Summary of First Inspection of Lahaina Plots on Hawaii

A number of plantings of Lahaina were made in the island of Hawaii in cooperation with Olaa Sugar Company, Ltd., Honokaa Sugar Company, Onomea Sugar Company, and Pepeekeo Sugar Company, for the purpose of root studies. The first examination of these plantings has proved a very enlightening experience.

While the *Pythium* type of root rot was present in varying degrees in all plots, in some fields it was in an aggressively active phase, viz.: Onomea at 400 feet and 1200 feet elevations, and Olaa at 1000 feet elevation, and possibly Honokaa upper field. It was less active at Olaa lower field, Honokaa lower field, and relatively quiescent at Pepeekeo, elevation 100 feet, at dates of observation.

The finding of the *Pythium* type of root rot in the Lahaina cane in all four localities of Hawaii, over a wide range of conditions, supports the view that this type of disease was an important factor in the earlier growth failure of Lahaina in the Hilo and Hamakua districts.

Of scientific interest was the finding of another closely related type of fungus, i. e., apparently a rough-walled oospore type of *Pythium* or *Aphanomyces* associated with root rot on all four of the plantations on Hawaii. Similar oospores were found for the first time at Wailuku in 1920 in relation with root rot in H 109.

Its significane: i. e., whether a harmless saprophyte following *Pythium aphanidermatum* chiefly in the soil conditions of Hawaii, or a parasite of importance, remains to be determined. Attempts will be made to isolate it in pure cultures for studies of parasitism. Two different *Pythium* types have already been isolated from Lahaina in Onomea Field 34, one being *P. aphanidermatum* and the other possibly the rough-walled *Pythium* oospore type.

In closing this first progress report in connection with the experimental plantings of Lahaina on Hawaii, it is a pleasure to acknowledge the kind and helpful cooperation I found everywhere at hand to facilitate the studies on root diseases.

A Study of the Relative Water Requirements of Long and Short Crops Under Intermittent and Non-Intermittent Harvesting

By H. W. Baldwin

As a basis for the following study of the Relative Water Requirements of Long and Short Crops, as influenced by the age of cane under various cropping schedules, we have assumed that plant cane will receive four irrigations the first month, three the second and two each month thereafter; and that ratoons will receive one irrigation every twenty-one days, or 1.4 irrigations per month.

We further assume that three months will be allowed for ripening the cane prior to harvest, on both long and short crops, no water being applied after the 15th and 21st months, respectively.

To facilitate calculations, Table I was prepared, using as a basis the data contained on page 38 of Renton and Alexander's report, submitted at the Forty-sixth Annual Meeting of the Hawaiian Sugar Planters' Association, 1926. Columns 1 and 2, taken from that report, represent a very fair average of the amount of water applied per irrigation, at various ages. Column 3 of the following table shows the amount applied to ratoons in 1.4 rounds per month, and column 4 shows the amount applied to plant cane in two rounds per month, etc.:

TABLE I

WATER REQUIREMENTS AT VARIOUS AGES

	Acre Inches					Total Water per Unit per Month			
		No. Irrigations per Month				Pl. 200A	Rat. 400A	Pl. 174A	Rat. 348A
Age Mo.	1	1.4	2	3	4	Inches	Mil. Gal. P. D.	Inches	Mil. Gal. P. D.
1	3.50	4.90	7.00	10.50	14.	4760	4.30	4141	3.76
2	3.75	5.25	7.50	11.25	..	4350	3.96	3785	3.44
3	4.00	5.60	8.00	12.00	..	3840	3.49	3340	3.04
4	4.50	6.30	9.00	....	..	4320	3.94	3760	3.40
5	4.75	6.65	9.50	....	..	4560	4.15	3930	3.58
6	5.00	7.00	10.00	....	..	4800	4.36	4175	3.80
7	5.12	7.15	10.24	....	..	4908	4.48	4261	3.88
8	5.25	7.35	10.50	....	..	5040	4.57	4386	3.98
9	5.35	7.50	10.70	....	..	5140	4.70	4575	4.15
10	5.50	7.70	11.00	....	..	5280	4.80	4605	4.19
11	5.75	8.05	11.50	....	..	5520	5.02	4800	4.37
12	6.00	8.40	12.00	....	..	5760	5.24	4915	4.46
13	6.50	9.10	13.00	....	..	6240	5.66	5425	4.94
14	6.75	9.45	13.50	....	..	6480	5.90	5740	5.21
15	7.00	9.80	14.00	....	..	6720	6.12	5860	5.34
16	7.25	10.15	14.50	....	..	6960	6.32	6050	5.52
17	7.50	10.50	15.00	....	..	7200	6.53	6260	5.70
18	8.00	11.20	16.00	....	..	7680	6.90	6695	6.10
19	8.25	11.50	16.50	....	..	7900	7.20	6878	6.26
20	8.50	11.90	17.00	....	..	8160	7.42	7119	6.48
21	8.75	12.25	17.50	....	..	8400	7.65	7310	6.66

For our first study we have assumed a 4800-acre short crop, the harvesting and planting to be carried on simultaneously, starting in January and running eight months, at the rate of 600 acres per month, of which 200 acres are plant and 400 acres are ratoons.

The 200 acres of plant cane would receive four irrigations the first month, or 14 inches per acre (column 6), or a total of 2800 inches. The 400 acres of ratoons would receive 4.9 inches (column 3) per acre, or a total of 1960 inches, a grand total of 4760 acre inches, which is found in column 7.

Column 8 represents the amounts in column 7, converted to million gallons per day. Using this column, we can now readily tabulate the total water requirements for each month.

The 600-acre unit starting in January requires 4.30 million gallons per day for the first month; 3.96 the second; 3.94 in March, etc. Similar units are started in February, March, April, May, June, July and August, and then there is an interval of four months until the next crop is started in January.

Schedule A represents the complete water requirements for one year:

SCHEDULE A

Short Crop Intermittent Million Gallons Per Day

Mo.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.30	4.30	4.30	4.30	4.30	4.30	4.30	4.30				
2		3.96	3.96	3.96	3.96	3.96	3.96	3.96	3.96			
3			3.49	3.49	3.49	3.49	3.49	3.49	3.49	3.49		
4				3.94	3.94	3.94	3.94	3.94	3.94	3.94	3.94	
5					4.15	4.15	4.15	4.15	4.15	4.15	4.15	4.15
6	4.36					4.36	4.36	4.36	4.36	4.36	4.36	4.36
7	4.48	4.48					4.48	4.48	4.48	4.48	4.48	4.48
8	4.57	4.57	4.57					4.57	4.57	4.57	4.57	4.57
9	4.70	4.70	4.70	4.70					4.70	4.70	4.70	4.70
10	4.80	4.80	4.80	4.80	4.80					4.80	4.80	4.80
11	5.02	5.02	5.02	5.02	5.02	5.02					5.02	5.02
12	5.24	5.24	5.24	5.24	5.24	5.24	5.24					5.24
13	5.66	5.66	5.66	5.66	5.66	5.66	5.66	5.66				
14		5.90	5.90	5.90	5.90	5.90	5.90	5.90	5.90			
15			6.12	6.12	6.12	6.12	6.12	6.12	6.12	6.12		
	39.1	48.6	53.7	53.1	52.6	52.1	51.6	50.9	44.8	40.6	36.0	37.3

Thus, taking the month of March for example, we have first a unit just starting, requiring 4.30 million gallons per day; another unit started the previous month, requiring 3.96 million gallons; then a unit which was started in January and now three months old, requiring 3.49 million gallons. The next unit, now eight months old, was started the previous August and requires 4.57 million gallons, etc. The total of this column, 53.7 million gallons, is the average amount of water required per day during the month of March. In like manner the other totals represent the requirements for the respective months.

We will now compare this short crop with a long crop under similar treatment. Obviously, the tonnage will be greater on a 24 months' crop and to get the same total yield, less acreage will be required. How much less would be required, is a matter for conjecture, as we have no definite data to go on. H. P.

Agee, in the *Proceedings of the Forty-sixth Annual Meeting of the H. S. P. A., 1926,* pages 35-37, assumes, for the purpose of argument, that a short crop of 18 months will yield 87 per cent of a 24 months' crop, and for lack of anything more definite we will assume this to be correct.

Eighty-seven per cent of 4800 acres is 4176 acres, which is the figure used in the long crop schedules. On an 8-month planting and harvesting schedule, each unit will consist of 522 acres, of which 174 acres will be plant and 348 acres ratoons. Schedule B has been worked out on this basis, and represents present common practice:

SCHEDULE B

Long Crop Non-Intermittent Million Gallons Per Day

Mo.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	3.76	3.76	3.76	3.76	3.76	3.76	3.76	3.76				
2		3.44	3.44	3.44	3.44	3.44	3.44	3.44	3.44			
3			3.04	3.04	3.04	3.04	3.04	3.04	3.04	3.04		
4				3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	
5					3.58	3.58	3.58	3.58	3.58	3.58	3.58	3.58
6	3.80					3.80	3.80	3.80	3.80	3.80	3.80	3.80
7	3.88	3.88					3.88	3.88	3.88	3.88	3.88	3.88
8	3.98	3.98	3.98					3.98	3.98	3.98	3.98	3.98
9	4.15	4.15	4.15	4.15					4.15	4.15	4.15	4.15
10	4.19	4.19	4.19	4.19	4.19					4.19	4.19	4.19
11	4.37	4.37	4.37	4.37	4.37	4.37					4.37	4.37
12	4.46	4.46	4.46	4.46	4.46	4.46	4.46					4.46
13	4.94	4.94	4.94	4.94	4.94	4.94	4.94	4.94				
14		5.21	5.21	5.21	5.21	5.21	5.21	5.21	5.21			
15			5.34	5.34	5.34	5.34	5.34	5.34	5.34	5.34		
16				5.52	5.52	5.52	5.52	5.52	5.52	5.52	5.52	
17					5.70	5.70	5.70	5.70	5.70	5.70	5.70	5.70
18	6.10					6.10	6.10	6.10	6.10	6.10	6.10	6.10
19	6.26	6.26					6.26	6.26	6.26	6.26	6.26	6.26
20	6.48	6.48	6.48					6.48	6.48	6.48	6.48	6.48
21	6.66	6.66	6.66	6.66					6.66	6.66	6.66	6.66
	63.0	61.8	60.0	58.5	56.9	62.6	68.4	74.4	76.5	72.1	68.1	63.6

The effect of intermittent harvesting is brought out very strikingly in Schedule C, which is the same as Schedule A, with the exception that operations are stopped during May and June and resumed in July:

SCHEDULE C

Short Crop Intermittent Million Gallons Per Day

Mo.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	4.30	4.30	4.30	4.30			4.30	4.30	4.30	4.30		
2		3.96	3.96	3.96	3.96			3.96	3.96	3.96	3.96	
3			3.49	3.49	3.49	3.49			3.49	3.49	3.49	3.49
4	3.94			3.94	3.94	3.94	3.94			3.94	3.94	3.94
5	4.15	4.15			4.15	4.15	4.15	4.15			4.15	4.15
6	4.36	4.36	4.36			4.36	4.36	4.36	4.36			4.36
7	4.48	4.48	4.48	4.48			4.48	4.48	4.48	4.48		
8		4.57	4.57	4.57	4.57			4.57	4.57	4.57	4.57	
9			4.70	4.70	4.70	4.70			4.70	4.70	4.70	4.70
10	4.80			4.80	4.80	4.80	4.80			4.80	4.80	4.80
11	5.02	5.02			5.02	5.02	5.02	5.02			5.02	5.02
12	5.24	5.24	5.24			5.24	5.24	5.24	5.24			5.24
13	5.66	5.66	5.66	5.66			5.66	5.66	5.66	5.66		
14		5.90	5.90	5.90	5.90			5.90	5.90	5.90	5.90	
15			6.12	6.12	6.12	6.12			6.12	6.12	6.12	6.12
	41.9	47.6	52.7	51.6	46.6	41.8	41.9	47.6	52.7	51.6	46.6	41.8

In like manner other schedules have been worked out, but only the totals for comparison need be given here as in Table II.

It will be noted that in each case intermittent harvesting results in a lessening of the water demands, during the dry summer months. On the other hand, speeding up the harvesting and planting from 8 months to 7 months increases the water demand during the months of May to October, inclusive.

The saving in water, effected by Schedule C (short crop, 8 months intermittent), over all other schedules is remarkable. The saving over present common practice (Schedule B) is still more noticeable, and is represented graphically in the illustration. During the four dry months, June, July, August and September, there is an indicated saving of from 20 to 25 million gallons per day, and this in spite of the greater acreage involved in the short crop schedule.

The writer does not wish to go on record at this time as advocating short cropping, as there are many other considerations than water to be studied. We are merely presenting one phase of the subject in the hope that it may be of some assistance in the study of the short cropping problem:

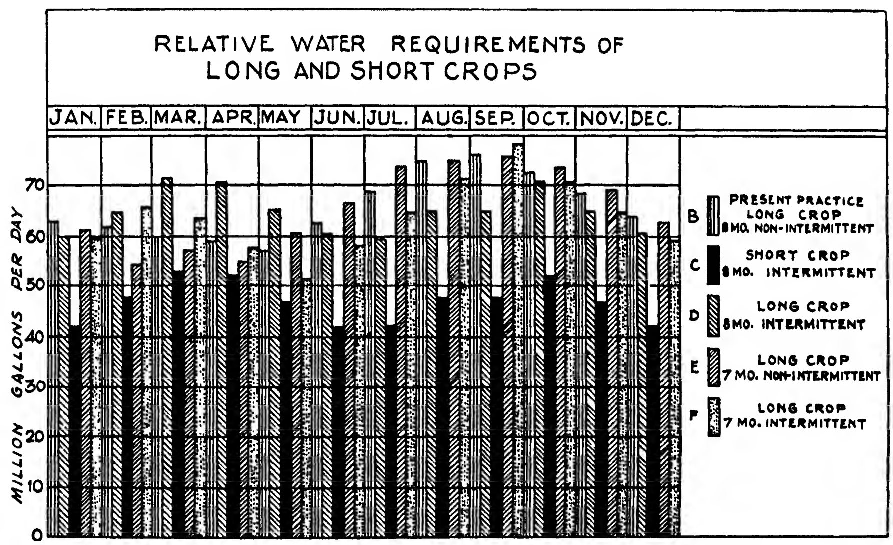

TABLE II

Water Requirements

Comparison of Long and Short Crops Under Intermittent and Non-Intermittent Harvesting

Million Gallons Per Day

Schedule	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
A	39.1	48.6	53.7	53.1	52.6	52.1	51.6	50.9	44.8	40.6	36.0	37.3
B	63.0	61.8	60.0	58.5	56.9	62.6	68.4	74.4	76.5	72.1	68.1	63.6
C	41.9	47.6	52.7	51.6	46.6	41.8	41.9	47.6	52.7	51.6	46.6	41.8
D	59.9	64.6	71.7	70.2	65.0	60.3	59.9	64.6	71.7	70.2	65.0	60.3
E	61.0	59.2	56.8	54.7	60.6	66.8	73.2	75.3	77.8	73.4	68.2	62.7
F	59.5	65.7	63.5	57.1	51.0	57.7	64.1	71.0	78.0	70.2	64.5	59.4
G	58.6	65.0	70.7	68.8	62.6	57.0	64.1	70.7	76.7	70.5	64.7	59.6
H	42.7	48.8	54.2	48.0	42.2	42.3	48.6	54.3	53.2	46.9	41.2	36.0
I	41.9	48.1	53.9	47.3	41.5	36.3	42.9	49.2	54.7	53.6	47.4	41.8

A. Short Crop: 8 months, non-intermittent; January-August, inclusive; 200 acres plant, 400 acres ratoon each month; total 4800 acres.

B. Long Crop: 8 months, non-intermittent (present practice); January-August, inclusive; 174 acres plant, 348 acres ratoons each month; total 4176 acres.

C. Short Crop: 8 months, intermittent; January-April, July-October; 200 acres plant, 400 acres ratoons each month; total 4800 acres.

D. Long Crop: Same as B, only intermittent; January-April, July-October.

E. Long Crop: 7 months, non-intermittent; January-July, inclusive; 200 acres plant, 400 acres ratoons; total 4200 acres. (Round numbers were used in this case instead of 198 and 396, as Column 8, Table II, calculated for 200 and 400 acres is near enough for our purpose in this case.)

F. Long Crop: Same as E, only intermittent; January-March, June-September.

G. Long Crop: Same as F, only January-April, July-September.

H. Short Crop: 7 months, intermittent; January-March, June-September; 226 acres plant, 452 ratoons each month.

I. Short Crop: Same as H, only January-March, July-October (3 months interval).

"Duty of Water"—A Relic of Early Irrigation Terminology

By W. P. Alexander*

This paper has been written to correct an erroneous impression which is generally prevalent in Hawaii as to the meaning of the term, "duty of water," and to urge that, due to its ambiguity, we give a clearer interpretation to our data by the adoption of standard terms which will better express what we want to say and prevent confusion.

The False Conception of the Term in Hawaii

If I am not mistaken, there are those who are in the habit of thinking of "duty of water" in relation to the amount of the crop produced. For example: Should one million gallons of water per acre give *three tons of sugar*, the duty of water is said to be high. This conception is not according to the best irrigation parlance. Duty of water *per se* has no reference to the weight of the crop grown. There is a specific duty of water for every set of conditions, and we cannot refer to ratio of water to tons of cane or sugar produced as "duty of water." It was coined to express the relation between a given quantity of water and *the area* which it serves.

History of the Term

Fortier (5), gives a good account of how Americans came to use the term, "duty of water," which is given substantially as follows:

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* Head of the Department of Agricultural Control and Research, Ewa Plantation Company, Ewa, Oahu.

In the language of Brown (17), "duty of water" is a technical term used by irrigation engineers to signify the amount of work that water may be expected or ought to do in irrigating crops, and is defined by him as "the measure of the efficient irrigation work that water can perform, expressed in terms establishing the relation between the *area* of crop brought to maturity and the quantity of water used in its irrigation." The expression "efficient irrigation work" implies that the water supplied to the crop is neither more nor less than what is best for it.

During the past fifty years or more the duty of water in India has been expressed as a rule in terms of that area of crop, expressed in acres, which a discharge of one cubic foot per second, abbreviated to "cusec," flowing continuously during the life of the crop, is able to bring to maturity.

When irrigation in the western part of the United States began to be studied in a technical and scientific way by the agents of the Federal and State Governments, they adopted the custom of British engineers in India in expressing the relation between water and crop, but frequently gave in addition the same information expressed in miner's inches or fraction thereof per acre. Inasmuch, however, as there are two crop seasons in each calendar year in India, in which the crops grown may differ widely in their water requirements, it naturally follows that in India the crop irrigated rather than the area of land served is emphasized. In this country, on the contrary, two crops are seldom grown on the same land in any one year and in consequence the duty of water is usually expressed as one cubic foot per second, abbreviated to one second-foot, to a certain number of acres which it irrigates.

Interpretation in the Western United States Neglects Crop Value

The opinion of many of the irrigation authorities in the Western United States has been sought as regards their definition and their interpretation of the term "duty of water."

From New Mexico, Bloodgood (2), offers this definition:

> Duty of water may be expressed as the number of acres of land that may be irrigated by a definite quantity of water, usually one cubic foot of water per second flowing continuously throughout the irrigation season; or as a certain quantity of water required to irrigate an acre of land, or in terms of total quantity of water used during an irrigation season. It is said to be high when a given quantity of water serves a large acreage, and low when it serves a small acreage.

and then he enumerates the following variable factors which tend to increase or decrease the duty of water:

(1) Kind and variety of crops.
(2) Method of delivery.
(3) Kind of distribution system.
(4) Preparation of the land surface.
(5) Method of application.
(6) Cultivation.
(7) Amount of water per irrigation.
(8) Economy and skill of user.
(9) Soil fertility.
(10) Climate—temperature, wind and rainfall.

From Colorado, Parshall (10), writes:

It is next to impossible to correlate the idea of duty of water for all conditions so that direct comparisons may be had. It will be appreciated that what might be the actual usage of water for one locality and particular crop, may not be that obtained for some other place with unlike physical conditions, but for the same crop.

To present the idea of duty of water various limitations have been imposed for the purpose of conveying a new thought. In some cases this has led only to confusion and uncertainty; however, all involving the fundamental conception of area to amount used. . . .

I do not think that the general conception of the idea of duty of water carries with it the element of least, economic, or best use of water. It will be noted that some authors seem to lend the impression that it is the least amount of water which will produce a given yield. This relation might be compared to the gasoline mileage of automobiles. The car that makes the most miles per gallon of fuel cannot be set up as the standard of comparison, because type of motor, weight of car, convenience of equipment, roads, length of journey and various other factors must needs be considered before any correlation would be possible. So with the idea of duty of water; many factors are involved, and it is, therefore, to be considered only from a general viewpoint.

I would conclude, therefore, that the expression ''duty of water'' be defined in its most general sense as that of area in acres irrigated by a continuous flow of one second-foot of water.

Different Examples of Duty of Water Show Area Basis

The following definitions of duty of water by House (6), also of Colorado, are confirmed by such authorities as Etcheverry (3), Widtsoe (14), Fortier (5), Winsor (16), Mead (8), Merriman (9), and Wilson (15):

Answering your question concerning a definition for the ''duty of water,'' will say—by ''duty of water'' we mean the *service* that it will render when used for irrigation purposes. ''Duty of water'' is usually expressed in one of two ways:

First, the amount of land that a unit flow of water will irrigate; said flow to continue throughout the entire irrigation season. The unit flow of water used is the second-foot and the amount of land is expressed in acres. Hence the ''duty'' is expressed in *acres* per *second-foot*.

Second, the amount of water necessary to irrigate and produce crops on a unit of land. The unit of land is the acre and the amount of water is usually expressed in *acre-feet per acre* or in acre-inches per acre, and represents the total amount of water applied to that land throughout the entire irrigation season.

In Arizona, Smith (11), states:

With regard to the term ''duty of water'' a broad definition would be—the relation between water supply and area of land served. This relationship has been stated in a great many different ways, sometimes as the quantity of steady flow in the supply ditch and sometimes as the total depth per annum. Furthermore, the term is used by some writers to include the canal losses and by others to exclude the canal losses. In the first case it should be specified as the duty of water at the diversion point, and in the second case, the duty of water at the land, or at the farmers' headgate. I might go further and say that there is a duty of water as actually practiced (and that is very variable) and there is also the duty of water that is idealized by irrigationists in which the losses are reduced to a minimum.

In Wyoming, Fitterer (4), gives examples which corroborate the above ideas:

Concerning the definition of duty of water I think of the same in two ways, one as a so-called static unit, and the other as a kinetic unit—that is, water either at rest or water on motion. In the *former* consideration we usually regard the duty of water in Wyoming as

about 2 feet, which of course means a seasonal covering of 2 feet vertically over the area in question necessary to mature an ordinary crop. This, it is true, is a variable quantity depending upon the crop raised, the particular season, etc., etc. In the *latter* method of measurement, we gauge the duty of water in terms of cubic feet per second flowing throughout the growing season necessary to mature an ordinary crop. Our state laws allow 1 cubic foot per second to every 70 acres, and when filings are made they are rated on this basis. This is very liberal under our climatic conditions. Our altitude is quite high for most of the state of Wyoming, and the seasons correspondingly short and the summer fairly cool. Again this method of expressing the duty of water is more or less variable, depending upon many factors.

In Utah, Israelsen (7), also points out:

It is common usage in Utah to speak of a duty of one second foot to 35 acres early during the season when water is plentiful. Later, during June, the duty is increased to one second foot for 50 acres. Still later, during July and August, the duty is increased sometimes as high as one second-foot for 100 acres.

The term duty is used also in a quantitative sense with respect to a month or entire irrigation season. For example: since one second foot running for a period of 30 days delivers approximately 60 acre feet, if this quantity were applied to 60 acres during the month of June, the duty would be said to be one acre foot per acre. Likewise, for the season it is common usage to express the duty of water as four acre feet per acre gross or three acre feet per acre net, provided 25% of the amount of water diverted from its natural source is lost in conveyance and distribution.

In California, Beckett (1), illustrates his definition as follows:

Concerning the term "duty of water." This is an ambiguous term and its use has led to considerable confusion. However, as commonly used, it is supposed to express the relation between quantity of water used and area of land served. This necessitates the use of the terms "gross" and "net" duty, and is further complicated by the number of ways in which this relationship may be expressed. This form of expression varies in the different localities and under different systems, and may take any one of the following forms:

(1) Number of acres served by 1 cubic foot per second.
(2) Number of acres served by 1 miner's inch.
(3) Directly in acre-feet, or acre-inches per acre.

If (1) or (2) is used another complication is encountered in that in order to be reduced to figures comparable with other localities the length of irrigation season or period through which delivery is made must be stated or assumed. As an example of this our water right on the University Farm states that it is entitled to a "delivery not to exceed 1 c.f.s. for each 120 acres irrigated." The number of acre-feet to which we are entitled depends upon the number of days constituting the irrigation season, and since this is not designated there is sometimes quite a difference of opinion as to the quantity which should be delivered.

An example of the use of this form may be found in the statement that the average gross duty of water for rice in Sacramento Valley is 1 c.f.s. per 40 acres, the net duty being 1 c.f.s. per 60 acres.

If we are to continue to use the term duty of water, we believe it should be expressed directly in acre-feet or acre-inches per acre, and we are using only these terms in reporting results of experimental work.

Modifications Are Necessary

Those engaged in irrigation recognize that it is often necessary to be more explicit and modify the term "duty of water," using:

(1) Gross duty;
(2) Headgate duty;

(3) Net duty;
(4) Economic duty;
(5) Seasonal duty.

The fine points are very clearly stated by Wadsworth (13), so as to be easily understood by the plantation man:

In reply to your questions with regard to the definition of the term "duty of water" I am glad to give you our opinion of the meaning of the term, but I am fully aware of the fact that the words are used in a wide variety of meanings. Because of this indefiniteness of expression we have coined four or five terms, each one dealing with a certain phase of duty of water investigations.

By gross duty of water we mean the ratio existing between the quantity of water diverted by a main canal and the area of the land served by that canal. If a canal company reports a gross duty of water of 4 acre-feet per acre it is understood that enough water passes the intake of this canal during the irrigation season to cover the irrigated area to a depth of 4 feet. There is evidently no indication of crop responses in this definition and no intimation that better yields might not be secured with a higher or a lower gross duty of water.

By net duty of water we mean that ratio existing between the quantity of water delivered to an individual's headgate to the area of land irrigated by that individual. The net duty is always higher than the gross duty inasmuch as conveyance losses are included in the latter. We have another unit of duty of water which has never received a satisfactory name. This unit expresses the relation between surface applications and area which results in the greatest crop return. This may be quite different from either of the units mentioned above. A canal company may exhibit a gross duty of 5 acre-feet per acre, an individual might use 3 acre-feet per acre, but with careful analysis in view of his particular soil type and other local conditions it might be demonstrated that he could secure a greater yield with 2 acre-feet per acre. As I say, there is no satisfactory name as yet for the application of water which will secure the greatest crop production.

It is not at all sure that the application of water which will result in greatest yield in tons per acre will be the application which would result in the greatest net profit in dollars per acre. In cases where water is costly and the yield resulting from an additional application of irrigation water is insignificant the lower application might be the application resulting in greatest net profit while the larger would result in greatest tonnage. So we have a unit called the *economic* duty of water, which is again a ratio between a quantity of water and an area of land, this application being the one which produces greatest net income to the grower. You will, of course, see that all factors entering into the cost analysis of a certain crop must be considered in the determination of this unit.

Winsor (16), differentiates between net duty and what he calls headgate duty:

In general I understand "duty of water" to mean the ratio between volume of water used and unit area of land served. We speak, for example, of: a duty of 6 acre-feet per acre, or 15 acre-inches per season, or 70 acres per second-foot. In the first two cases we have the ratio expressed in volume of water per unit of land served. In the last case we speak of the area served by a given stream of water, without reference to any time limit.

We are more explicit when we speak of "gross duty," "headgate duty," or "net duty." The first two terms used here are plain enough, the gross duty being the volume measured at its source divided by the total area of irrigable land served; and in the second case the volume measured at the headgate of the farm, divided by the total area served. The result is stated in terms of unit volume per unit area irrigable. There is, however, much confusion in the use of the term "net duty." Some authorities refer to net duty as the volume of water used per acre after deducting losses in transit. In my opinion this use is incorrect and really is more properly the *headgate duty.* Net duty, as I understand it, is the amount of water which is taken up by the soil in the process of irrigating any particular unit area of crop, i.e., the headgate volume less the surface runoff divided by the area served. This

does not take into account the rainfall nor the loss through deep percolation. Furthermore, in this meaning of net duty, moisture from rainfall is not taken into account, nor is loss of water through deep percolation deducted. The term applies to the amount of water actually absorbed by the soil.

It is doubtful whether we in Hawaii need to consider this technical point.

Unanimous Dissatisfaction With Term "Duty of Water"

No one who was consulted was satisfied with the term "duty of water." How it originated has been touched upon by Fortier (5), who further comments as to why we continue to use it.

The state administrative officer, charged with the duty of allocating the public waters within his jurisdiction to those entitled to its use, is guided mainly by what courts and other tribunals have determined to be the duty of water for defined areas of land. As these determinations have been expressed for the most part as a unit of flowing water (a miner's inch or cubic foot per second) for a certain number of acres he naturally makes use of the same terms in apportioning the flow of a stream. Likewise the engineer who designs and constructs irrigation works is mainly concerned with the conveyance of given quantities of water from the point of diversion to the place of use, and for him the cubic foot per second or second-foot is the most convenient unit to adopt.

The farmer, on the other hand, is concerned with another phase of irrigation. His main object is to grow a profitable crop, and under arid and semi-arid conditions water is the main element in achieving this end. He therefore desires an adequate supply of water for his crops to meet each varying stage of their growth.

The farmer has never taken kindly to the term duty of water. He has no objection to the word "duty" being applied to a machine, but just why it should be applied to the quantity of water passing through his delivery box is not apparent to him. This has puzzled many who are not farmers.

To force an engineering term on the agriculturist, which is meaningless to him, is not wise unless the engineering features are of greater importance. In the case of irrigation the importance of the agricultural phase greatly surpasses the engineering. Engineering works are simply means to an end. They are usually the products of a few months' work by nomad engineers who are here today and gone tomorrow. On the other hand, the man who raises crops is usually pretty well rooted to the soil and must carry on year after year.

Wadsworth (13), at Davis, also objects to its use.

In my opinion the use of the term duty of water and its incorporation into literature is extremely unfortunate. I have often suggested to Professor Adams that we abandon its use and talk of something a little more concrete in its meaning. In his opinion the words are too deeply rooted in irrigation literature to ever get rid of them. My principle objection to the word duty in this connection is that it implies maximum achievement, whereas it is simply a measure of existing practice. You will, of course, appreciate that a high duty as we understand it means a relatively small application in terms of acre-feet per acre. I presume the philosophy is that in such a case water is working hard and a little of it goes a long way. At first glance it seems inconsistent, however, to be told that a duty of water of 2 acre-feet per acre is a higher duty than 3 acre-feet per acre. However, such is the commonly accepted meaning of the term.

Winsor (16), writes:

Frankly, it is my opinion that the whole terminology in irrigation practice should be subjected to a thorough overhauling, and should have ambiguities removed and terms added where necessary, and eliminated where uncertain or unnecessary.

Veihmeyer (12), is willing to discard the term duty of water in favor of "use of water."

I have felt that the use of this term (duty of water) is not entirely satisfactory, and I see no advantage in its use over that of such expressions as the "use of water." For instance, the "use of water under the canal system" which would be comparable to gross duty and "use of water on the individual farm" in the same sense that net duty is now used.

Constructive Criticism Suggests Better Phrases

If the term duty of water is unsatisfactory, one must find a term which will meet the needs of the agriculturist and irrigation overseer; that will be simple and easily understood by the non-technical man. The following terms should be applicable to Hawaiian irrigation practice:

(1) Water requirements;
(2) Irrigation requirements;
(3) Use of water;
(4) Consumptive use of water.

Duty of water, in the accepted usage, implies actual use of the water in practice rather than the actual need of the plant. The definitions of the first two terms have been formulated by Fortier (5), bearing in mind the crop grown is paramount in all irrigation studies:

The term "water requirement" of sugar cane is the quantity of water including the effective natural precipitation and available soil moisture required for profitable crop yield at each stage of growth from the time of planting to harvesting under the physical and normal climatic conditions of the locality.

A definition of the term "irrigation requirement" might be expressed somewhat similarly, with this difference, however, that it would exclude effective precipitation and soil moisture, but be dependent upon both as well as upon the character of the soil and other physical and climatic conditions. It might be worded in some such way as this:

The term "irrigation requirement" of sugar cane is the quantity of water required to supplement at the right time the natural precipitation and ground water in such a way to produce satisfactory yields.

The requirements of the cane for water are not always met under variable weather conditions, and it is recommended that as agriculturists we refer to the "use of water" instead of the duty of water. We will have data on the "net use of water" when the amount of water applied to the fields has had deducted all transmission losses between the headgates and field intake. Gross use will be defined as the total amount of water pumped or supplied the plantation from mountain streams measured at the source. The ratio of water to the weight of the crop and to the area covered can be expressed without complications, and the confusions as to what is meant by a low or high duty will be obviated. There will be an economic use of water (on an acre and per ton sugar basis) dependent on the many factors of cost of production and returns from sale of the crop.

In the western United States, where soil moisture studies are made, the term "consumptive use of water" is finding favor. As yet we have no data in Hawaii which would give the consumptive use of water for sugar cane, but one should be familiar with this term when literature mentions it. According to Israelsen (7), "the consumptive use" is defined and interpreted as follows:

The consumptive use, is the amount of water in acre-feet per cropped acre per year absorbed by the crop and transpired or used directly in the building of plant tissue, together with that evaporated from the crop-producing land.

The direct source of "consumed" water is the water in the soil in any form so that crops can absorb it. The indirect sources of "consumed" water are those parts of the natural precipitation and of irrigation water which are stored in the soil in such depths and for such time as to permit absorption by crop roots together with such water as may be obtained by the crop roots from the water table. The consumptive use as here defined is, therefore, equal to the total evapo-transpiration.

It is a theoretical figure that cannot be obtained in field trials, as the investigator must have an elaborate equipment of tanks to determine the water actually used in the physiological process of the plant.

Conclusion

There is a decided tendency among modern irrigation investigators to have a rational terminology that can be understood by all. To accomplish this end the ambiguous term "duty of water" brought to America from India by engineers can be eliminated. "Use of Water" and "Water and Irrigation Requirements," are phrases that express much more plainly to the field man of today the relationship of water to his land and crops.. Before we are still further misled and our recent investigations in Hawaii are published, it will be a progressive move if the plantation men forget the term "duty of water," which is often misused and leads to confusion, and adopt a nomenclature which is simple and clear cut.

Acknowledgment

The assistance rendered in collecting the information presented in this report by those who have made "Irrigation" their life work is greatly appreciated, and the writer wishes to take this opportunity to thank all who contributed in defining and interpreting the term, "Duty of Water."

Literature Cited

(1) Beckett, S. H., Professor of Irrigation Practice, University of California, Division of Irrigation Investigations and Practice, Davis, California—Letter dated—December 20, 1926.

(2) Bloodgood, Dean W., Associate Irrigation Engineer, U. S. Department of Agriculture—Net requirements of crops for irrigation water in the Mesilla Valley, New Mexico.

(3) Etcheverry, B. A., Irrigation Practice and Engineering—Volume 1.

(4) Fitterer, J. C., Professor of Irrigation Engineering, The University of Wyoming—Letter dated—December 24, 1926.

(5) Fortier, Samuel, Senior Irrigation Engineer, U. S. Department of Agriculture, Berkeley, California—Letter dated—December 13, 1926. Use of water in irrigation—Page 209, Edition 1926.

(6) House, E. B., Professor of Irrigation Engineering, The Colorado State Agricultural College, Fort Collins, Colorado—Letter dated—December 13, 1926.

(7) Israelsen, O. W., Professor of Irrigation and Drainage, Utah Agricultural College—Letter dated—December 20, 1926.

(8) Mead, Elwood, Office of Experiment Stations. Bulletin No. 86, page 33.

(9) Merriman, Mansfield, American Civil Engineers' Hand Book, page 1818.

(10) Parshall, R. L., Irrigation Engineer, U. S. Department of Agriculture, Fort Collins, Colorado—Letter dated—December 17, 1926.

(11) Smith, G. E. P., Irrigation Engineer, University of Arizona—Letter dater—December 11, 1926.

(12) Veihmeyer, F. J., Assistant Professor of Irrigation Investigations and Practice, University of California; Division of Irrigation Investigations and Practice, Davis, California—Letter dated—December 18, 1926.

(13) Wadsworth, H. A., Assistant Professor of Irrigation Investigations and Practice, University of California; Division of Irrigation Investigations and Practice, Davis, California—Letter dated—December 9, 1926.

(14) Widtsoe, John A., Bulletins Nos. 116 and 117, Utah Agricultural College, Experiment Station.

(15) Wilson, Herbert M., Irrigation Engineering, page 447.

(16) Winsor, L. M., Associate Irrigation Engineer, U. S. Department of Agriculture, Berkeley, California—Letter dated—January 20, 1927.

(17) Brown, Hanbury—Irrigation, its principles and practice, as a branch of engineering.

Sugar Cane Mosaic and Insects

By Fred C. Hadden

Introduction

This paper deals with the entomological aspect, in Hawaii, of the relationship between insects and mosaic diseases, emphasizing the part played by the corn aphis, *Aphis maidis* Fitch, as a carrier of the disease, as established by Brandes and confirmed by Kunkel and others. The writer wishes to express his thanks to Otto H. Swezey for helpful suggestions; also to H. Atherton Lee for advice and for aid in determining grasses. This work has been carried on between the dates August 1, 1925, and May 9, 1927.

The purpose of the work was to answer the following questions:

1. What insects transmit cane mosaic?
2. What is the life history of the corn aphis, and its rate of reproduction in Hawaii?
3. What grasses serve as favorable hosts for aphis?
4. What grasses are a source of mosaic infection, and to which grasses can mosaic be transmitted?
5. Do winged and/or wingless aphis transmit mosaic?
6. What are the actions of aphis when transferred to new hosts?
7. What are the death factors of aphis?
8. How can mosaic be reduced?

Mosaic characteristics have been described by other authors, namely, Brandes (1), Lyon (8), Kunkel (6), and Stahl (7); and nearly every one has observed mosaic on sugar cane, bristly foxtail, and corn; therefore, it is not necessary to give in this paper a detailed description of the effect of the disease on grasses.

But attention should be called to the fact that different species and varieties of grasses appear quite differently when affected by the disease. For example, in certain varieties of sugar cane (8) the mottling is fine and the elongate light colored areas are small; in other varieties the light colored areas are large and long, giving a streaky appearance to the leaf. In the same variety of corn both the fine type and the striping may occur. This may indicate that the same kind of mosaic may take on a different form (appearance) on different hosts; or there may be more than one kind of mosaic on these hosts.

In these experiments no attempt was made to determine if there is more than one kind of mosaic. In the future experiments will be conducted to prove the presence of one or more kinds of mosaic in corn and other grasses.

Stahl (7) has proven that in Cuba corn stripe is transmitted by the corn leaf-hopper and that sugar cane mosaic is transmitted by the corn aphis. It will be interesting to discover if the same thing occurs in Hawaii.

It has been definitely proved that insect vectors are the main cause for the spread of mosaic diseases in a number of Dicotyledons. But these diseases are often easily transmitted artificially by needle punctures, grafting, and hypodermic injections. Sugar cane mosaic, on the other hand, is transmitted artificially only with great difficulty.

No organism has ever been found to cause mosaic, or at least it has never been recognized as the causative agent. For this reason the disease is said to be due to a filterable virus, meaning, that it is impossible to filter out the material from a solution causing the disease. The only thing we are sure of is the effect of the disease on the leaves which results in a mottling or streaking (striping) of the leaves, the affected area being lighter in color than the normal green of the leaf. This is due to the action of the virus reducing the amount of chlorophyll in the affected areas, forming a chlorotic condition. The clearness or distinctness of diseased plants varies considerably; later, on the same plant it is impossible to decide whether it is really diseased or not. This is true of sugar cane, corn and sorghum. Fertilizing with ammonium sulphate usually results in the disease becoming very distinct within a week.

Experimental Methods

Experiments were conducted on large tables upholding 50 to 60 8-inch pots, or 30 to 40 12-inch pots. The legs of these tables were placed in pans of water to prevent ants and cockroaches from interfering with the experiments. Insect-proof cages were made from large glass lantern globes and heavy wire screen cylinders. These were covered with a fine grade of cheese cloth. Except in a few cases these cages covered the plants experimented with until a few days before the end of the experiment; they were then removed and the plants were sprayed, to kill any remaining insects, and fertilized to bring out indications of mosaic. These cages were entirely insect-proof, as shown by examination with a binocular and the fact that no checks became infested with aphis or mosaic.

During the first six months, only seedlings of sugar cane and grasses were used, but later these could not be obtained, so Striped Tip and Yellow Tip seed pieces

from Manoa substation were used. Since only one check out of 200 became mosaic it may be presumed that all such seed was healthy and free from mosaic. Only cane experimented upon with mosaic-infested aphis ever became diseased.

The evidence developed in these experiments indicates that sugar cane mosaic is the same as the mosaic found on nearly all the other grasses in Hawaii, or at least they are all various forms of the same disease. This point is upheld by the fact that the disease is readily transmitted back and forth between several of these grasses.

Experiments With Insect Vectors

Two insects have transmitted the disease: the corn aphis from various grasses to cane and other grasses; and the corn leafhopper, *Peregrinus maidis* (Ashm.), from corn to corn and in one case from corn to Striped Tip cane.

The following insects have repeatedly failed to carry or transmit mosaic from mosaic plants to healthy ones:

1. Sugar cane aphis—*Aphis sacchari* Zehnt.
2. Sugar cane leafhopper—*Perkinsiella saccharicida* Kirk.
3. Grass leafhopper—*Stictocephala festina* (Say).
4. The Blue (or green) Sharpshooter—*Draeculacephala mollipes* (Say).
5. Sugar cane leafmite—*Tetranychus exsiccator* Zehnt.

Life History of the Corn Aphis

An idea of the rapid growth and multiplication of the corn aphis from one female are indicated by the following data and discussion:

Date	Number of Aphis
August 26, 1925	1
August 27, 1925	2
August 28, 1925	3
August 29, 1925	4
August 31, 1925	6
September 1, 1925	9
September 3, 1925	13
September 5, 1925	27
September 9, 1925	67
September 14, 1925	223
September 17, 1925	371

These data were taken from Pot 6, dwarf evergreen broom corn. The plants were seedlings, two inches high with three leaves, at the beginning of the experiments. Later the aphis became so numerous that the plants became smutty and finally died.

The aphis first placed on the plants was full-grown and producing young when it was removed from Pot 4, dwarf evergreen broom corn. It produced one young every day up to September 1, when it died. At this time its first offspring had produced two young. By September 5, all the old adult's offsprings were reproducing. On the 14th of September, the third generation was reproducing,

and this accounts for the increase in count from 223 to 371. It was only during this late stage that the aphis became numerous enough to be really noticeable, and it seemed as though they had sprung into being overnight. Sometimes a single aphis may produce two or even three young a day, if conditions are favorable; i. e., warm and not too humid. Along about the fourth or fifth generation, winged forms appear. It is these winged forms that are more apt to carry mosaic because they have a rapid means of transportation on air currents.

Ten days after an aphis is born it begins to reproduce, and it may produce from one to two young every day for twenty days. In the meantime the second generation begins to reproduce, and by the end of thirty days the third generation are reproducing; so in a very short time the number of descendants from one aphis is enormous. In two months the offspring of one aphis would be over 1,000,000, provided conditions were suitable and that each aphis lived thirty days. However, this rapidity of reproduction is only approached upon sorghum, corn, and Sudan grass, never on any of the other grasses.

Hosts of the Corn Aphis

The corn aphis has been found reproducing (either in the field or in experiments) upon the following grasses:

1. *Panicum torridum* Gaud.—Hairy panicum grass.
2. *Panicum barbinode* Trin.—Para grass.
3. *Panicum maximum* Jacq.—Guinea grass.
4. **Holcus sorghum* L.—Sorghum.
5. **Holcus sudanensis* (Piper)—Sudan grass.
6. *Holcus sorghum* var.—Broom corn.
7. *Holcus sorghum* var.—Dwarf Evergreen Broom Corn.
8. *Zea mays* L.—Sweet or ear corn.
9. **Chaetochloa verticillata* (L.)—Bristly foxtail grass.
10. **Cenchrus hillebrandianus* Htch.—Burr grass.
11. *Syntherisma chinensis* (Nees).
12. *Syntherisma sanguinalis* (L.)—Crab grass.
13. *Syntherisma pruriens* (Trin.)—Pig grass.
14. *Eragrostis cilianensis* (All.)—Stink grass.
15. *Valota insularis* (L.)—Chase grass.
16. *Chloris paraguayensis* Steud. (Sw.).
17. *Chloris radiata* (L.).
18. *Eleusine indica* (L.)—Goose grass.
19. *Tricholaena rosea* Nees—Red top.
20. *Paspalum orbiculare* Forst.
21. *Paspalum fimbriatum* H. B. K.
22. *Saccharum officinarum* L.—Sugar cane.
23. **Echinochloa colonum* (L.)—Paddy grass.
24. *Echinochloa crusgalli crus-pavonis* (H. B. K.).
25. *Hordeum vulgare* L.—Barley.

26. *Avena sativa* L.—Oats.
27. *Triticum aestivum* L.—Wheat.
28. *Oryza sativa* L.—Rice.
29. *Capriola dactylon* (L.)—Bermuda grass.
30. **Holcus halepensis* L.—Johnson grass.
31. *Coix lachryma-jobi* L.—Job's tears.
32. *Dactyloctenium aegyptium* (L.).
33. *Sporobolus diander* (Ritz.).
34. *Heteropogon contortus* (L.)—Pili grass.

Those with asterisk were found to be most commonly infested with aphis. Bristly foxtail grass, the most widespread grass on Oahu, was usually found to have both mosaic and aphis. Aphis were never found to be numerous on foxtail, and at times it was very difficult to find this grass with either aphis or mosaic, or both.

Transmission of Mosaic Disease

Transmission of mosaic to cane more than two months old is very difficult and can usually be accomplished only after the cane has been heavily cut back, exposing the tender inner leaves of the spindle to the proboscis of the aphis.

At first young seedlings of grasses and cane were used; later, seed pieces of Striped Tip and Yellow Tip. The seed was carefully selected from cane growing in the Manoa substation. That this cane was free from mosaic was shown by the fact that, with only one exception, all seed from this source produced healthy, non-diseased plants unless experimented upon with mosaic-infected corn aphis.

So far, I have been unable to transmit mosaic from cane to any other grasses owing to difficulties in raising non-mosaic-infested corn aphis on mosaic cane.

At first the resistant Hawaiian-grown corn seed was used, but the results were unsatisfactory because this corn did not show mosaic characters distinctly. Later Golden Bantam seed was procured from the States, and this proved very satisfactory, as it showed very clearly mosaic markings.

Mosaic has been transmitted experimentally as indicated by the following table which shows: the number of the pot or cage experimented upon, the grass from which aphis vectors were taken, the plants becoming infected, the vector, the time period between the transfer of the vector from the mosaic to the healthy plants, and the appearance of the disease on the new host.

1927 EXPERIMENTS

Pot No.	Source of disease		Infected plant	Vector	Time period
8	Corn	to	Striped Tip	20 corn leafhoppers	19 days
10	Sorghum	to	Striped Tip	100 aphis	54 days
12	Sorghum	to	Striped Tip	500 aphis	19 days
14	Sorghum	to	Striped Tip	300 aphis	36 days
16	Sorghum	to	Striped Tip	200 aphis	19 days
18	Sudan	to	Striped Tip	50 aphis	32 days
22	Sorghum	to	Striped Tip	300 aphis	18 days

24	Sorghum	to	Striped Tip	200 aphis	18 days
30	Foxtail	to	Striped Tip	30 aphis	9 days
32	Foxtail	to	Striped Tip	60 aphis	32 days
33	Foxtail	to	Striped Tip	30 aphis	14 days
34	Foxtail	to	Striped Tip	30 aphis	9 days
35	Foxtail	to	Striped Tip	30 aphis	9 days
37	Foxtail	to	Striped Tip	30 aphis	9 days
38	Foxtail	to	Striped Tip	30 aphis	9 days
400	Corn	to	Corn	1 adult corn leafhopper	34 days
402	Corn	to	Corn	3 corn leafhoppers	17 days
404	Corn	to	Corn	12 corn leafhoppers	17 days
405	Corn	to	Corn	14 corn leafhopper nymphs	17 days
409	Corn	to	Corn	10 corn leafhopper nymphs	31 days
422a	Foxtail	to	Sorghum	20 corn aphis	20 days
423a	Foxtail	to	Foxtail	20 corn aphis	20 days

1925-26 EXPERIMENTS

Pot No.	Source of disease		Infected plant	Vector	Time period
46a	Sorghum	to	*Syntherisma chinensis*	30 corn aphis	77 days
65	Foxtail	to	Foxtail	15 corn aphis	12 days
124	Sorghum	to	ST x H109	40 corn aphis	31 days
140	Foxtail	to	YT x H109	50 corn aphis	22 days
141	Corn	to	OP26 x ST.H109	10 corn aphis	24 days
143	Foxtail	to	OP5YT x H109	30 corn aphis	19 days
144	Foxtail	to	OP5YT x H109	30 corn aphis	11 days
147	Foxtail	to	OP6ST x H109	35 corn aphis	27 days
149	Sorghum	to	OP5YT x H109	200 corn aphis	14 days
184	Crab grass	to	OP6ST x H109	25 wingless corn aphis	18 days
205	Sorghum	to	*Syntherisma chinensis*	200 wingless corn aphis	67 days
219	Sorghum	to	Chase	200 corn aphis	57 days
225	Foxtail	to	Corn	15 corn aphis	42 days
229	Sorghum	to	Corn	30 corn aphis	28 days
232	Foxtail	to	Foxtail	18 corn aphis	77 days
233	Sorghum	to	Foxtail	340 corn aphis	74 days
235	Sorghum	to	Sorghum	30 corn aphis	50 days
243	Foxtail	to	Foxtail	*Needle punctures*	41 days
243d	Foxtail	to	Foxtail	*Needle punctures*	19 days
243b	Sorghum	to	Foxtail	30 winged corn aphis	101 days
254f	Corn	to	Corn	12 corn leafhoppers	37 days
258d	Sorghum	to	Foxtail	20 corn aphis	13 days
258h	Sorghum	to	Foxtail	20 corn aphis	13 days
259b	Sorghum	to	Corn	60 corn aphis	13 days
260a	Sorghum	to	Corn	20 aphis	13 days
260d	Sorghum	to	Corn	20 aphis	13 days
260g	Sorghum	to	Corn	20 aphis	13 days
263a	Sorghum	to	Corn	45 aphis	20 days
263b	Sorghum	to	Corn	45 aphis	16 days
263c	Sorghum	to	Corn	45 aphis	11 days
264a	Sorghum	to	Sorghum	60 aphis	29 days
264b	Sorghum	to	Sorghum	50 aphis	25 days
300	Sudan	to	Striped Tip	20 aphis	38 days
301	Sudan	to	Striped Tip	20 aphis	38 days
303	Sudan	to	Striped Tip	20 aphis	38 days
306	Sudan	to	Striped Tip	10 aphis	40 days

307	Sudan	to	Striped Tip	24 aphis	40 days
309	Sorghum	to	Yellow Tip	15 aphis	45 days
311	Sorghum	to	Yellow Tip	15 aphis	45 days
316	Sorghum	to	Yellow Tip	15 aphis	45 days
320	Foxtail	to	Yellow Tip	10 aphis	32 days
322	Foxtail	to	Yellow Tip	10 aphis	32 days
325	Foxtail	to	Yellow Tip	? aphis	49 days
327	Sudan	to	Yellow Tip	? aphis	42 days
328	Sudan	to	Yellow Tip	? aphis	42 days
332	Sudan	to	Striped Tip	? aphis	42 days

At all times there was at least one check of the same kind near the plant experimented upon, and in many cases there were from two to three checks present. Throughout the entire period of these experiments only one check became mosaic.

Canes marked OP26 x ST.H109, OP5YT x H109, ST x H109, YT x H109, etc., were seedlings.

For every experiment that was a successful transmission there were at least three to five unsuccessful attempts, and in many cases twenty to thirty attempts at transmission were failures (this was during the hotter summer months). As many as 100 to 500 aphis were used in some of the experiments that were failures.

The experiments indicate that temperature and humidity are very important factors in the development and transmission of mosaic. In the warmer summer months it was very difficult to transmit the disease, but in the cooler winter months mosaic was more readily transmitted; but even under the latter conditions there were many unaccountable failures. The maximum temperature at which mosaic may be carried and developed is probably near the average temperature of our three coolest winter months.

Twenty-two different transmissions were made in these experiments; namely:

From Corn to Striped Tip, Corn, OP26 x ST.H109, and Foxtail.

From Sorghum to Striped Tip, *Syntherisma chinensis,* OP5ST x H109, Chase, Corn, Foxtail, Sorghum, and Yellow Tip.

From Foxtail to Striped Tip, Sorghum, Foxtail, YT x H109 (Seedling), OP5YT x H109, OP6ST x H109, Corn, and Yellow Tip.

From Crab grass to OP6ST x H109.

Possible Recovery of Diseased Plants

Three pots of mosaic sorghum were kept for over a year, March 26, 1926, to March 31, 1927, to find out if they would remain affected. They did so throughout this length of time. Sudan grass, H 109, Striped Tip, and Yellow Tip gave the same results. The distinctness or clearness of the mosaic streaks varied, being sometimes more distinct and sometimes scarcely perceptible. These plants were all repeatedly ratooned and fertilized. Four days after fertilization the plants greened up and the mosaic showed up distinctly.

These experiments indicate that the above plants do not grow out of a mosaic condition in Honolulu in the period of one year; probably they never do.

Grasses Affected With Mosaic Disease

The following grasses have been found with mosaic and may be a source of infection:

1. Corn. Commonly.
2. Dwarf Evergreen Broom Corn.
3. Evergreen Broom Corn.
4. Sorghum. Commonly.
5. Bristly Foxtail. Commonly.
6. Para grass—*Panicum barbinode.* Rarely.
7. Pig grass—*Syntherisma pruriens.* Occasionally.
8. Sudan grass.
9. Hono Hono grass—not a grass.
10. *Syntherisma chinensis* (Nees). Occasionally.
11. Sugar cane—*Saccharum officinarum* L.
12. *Echinochloa* sp. at the Hind-Clarke Dairy.
13. Job's Tears—Coix lachryma-jobi L.
14. Crab grass—*Syntherisma sanguinalis* (L.).
15. *Valota insularis*—Chase.
16. Hilo grass—*Paspalum conjugatum* (L.).
17. *Sporobolus diander* (Ritz.).

The most commonly found and widespread grasses with mosaic were foxtail, corn, sorghum, Sudan, sugar cane, pig grass, crab grass, and *Syntherisma chinensis.*

Observations on the Actions of the Corn Aphis

Four aphis were placed on a clean horizontal blackboard. Their original position was marked with a piece of chalk, and their trails were followed by drawing the chalk along behind them. The general direction of the trails of all four aphis was towards the window, near which they were placed. The following table shows how far the aphis traveled as measured along their trails, the time consumed, and the straight distance between starting point and finish:

Aphis No.	Size	Trail distance	Distance in straight line	Time
1	¾ grown	30 ins.	24 ins.	1 hr.
2	¾ grown	36 ins.	27 ins.	4 hrs.
3	½ grown	8 ins.	6 ins.	4½ hrs.
4	Full-grown adult	40 ins.	30 ins.	4½ hrs.

All four aphis were wingless and healthy and were not injured in being transferred from the sorghum by the camel's hair brush. At times they had difficulty in crossing the chalk marks. This experiment was twice repeated with similar results; it indicates how far aphis may travel under the most favorable conditions on a smooth surface. When the conditions are changed but slightly, the aphis are hopelessly lost and may not travel more than two inches in as many hours. This is especially true if the ground is slightly dusty, plowed, cultivated, rough, or gravelly. Only on the smoothest ground can aphis travel any appreciable distance,

and then with great difficulty. Thus it seems most improbable that wingless aphis may crawl from mosaic grasses which have been cut down onto cane and infect it; the chances are, in fact, very remote, because they encounter even greater difficulties when they enter the stiff, spiny hairs on the leaf sheaths of H 109 and many of the other varieties.

It is only from the winged forms that real danger is to be expected, and these are probably the main vectors of the disease for the following reasons:

1. They are produced by the drying up of the host, and
2. By the ripening of the host as the seeds are produced.
3. Another factor at this time is the loss of protection in the curled-up terminal leaves of plants going to seed.

In the field, grasses which are weeds are generally left until they go to seed before they are cut down. By this time the aphis on these grasses have developed into winged forms and have deserted the drying host, flying to sugar cane and other grasses.

These experiments indicate that mosaic is more readily transmitted to cane under two months old, either ratoon, seed piece, or seedling, and especially to plants which have had the central spindle cut off short so that the young light green or yellow, tender inner leaves are forced out by the growth of the cane and are exposed to the attacks of these aphis. It is usually in younger cane that weeding is necessary, and as some of the cane is always cut at the same time, ideal conditions for the transmission of mosaic by aphis are produced. This brings out the point that grasses which are weeds should be cut when small, before they go to seed and before they begin to dry up; and care should be taken not to cut the cane at the same time.

Corn aphis were transferred from grass hosts of one species and placed on other species, carefully watched under the binocular microscope and their actions noted. Some of the transfers thus made and observed were from corn to cane, sorghum, Sudan, and bristly foxtail; and from various grasses to cane. In nearly every case the aphis crawled around on the new host plant until a suitable place was found to feed. While crawling, the aphis holds the body at some distance from the host plant, stopping occasionally to insert the proboscis. Six or seven trials are usually attempted before the final deep insertion (½-1 mm.) of the beak is made for feeding. It is easy to see when the aphis commence feeding, for they then lie close to the host plant, in fact against it, and a pumping motion becomes apparent.

In almost every experiment the aphis were feeding within five or ten minutes after transfer to the new host. They had greater difficulty in inserting the beak in older cane than in younger cane (under six weeks old), as shown by the fact that in younger cane they were usually feeding after only two or three attempts to insert their beaks; but on the older canes as many as eight or nine attempts were made before they could sink their proboscis into the tissues of the new host. The aphis wandered around much more on the older plants than on the younger, this evidently being due to the fact that they were encountering difficulties in locating a favorable place for feeding. There can be no doubt that the aphis encounter great

difficulty in inserting the proboscis in the harder (more siliconized) leaves of the older cane.

It is also certain that in some of the thicker leaved cane it would be impossible for aphis, especially corn aphis and any kind of young aphis, to reach the phloem from the upper surface; the distance from above is greater than the length of the proboscis, without taking into consideration the fact that the beak may not go straight into the phloem through the cells, but probably between the cells, following the intercellular spaces and the line of contact of two cell walls which may be weak and separate, allowing the beak to penetrate in this manner. Incidentally, aphis pierce the epidermis at random and may or may not make use of the stomata; they probably do so very rarely and then only accidentally.

Aphis settle down to feeding much sooner on young grasses than they do on older grasses, and young or old cane, even though they have been starved for a day or two.

A cross section of a cane leaf reveals other causes for the difficulties encountered by aphis in feeding. The vascular bundles of sugar cane are shown* to be composed of xylem and phloem surrounded by a starch sheath, and the starch sheath, in turn is surrounded by parenchymous tissue; next to this lie the cells rich in protoplasm, the giant cells, and then at intervals along the upper surface of the leaf, the motor cells which are also giant cells.

The xylem cells are above, towards the upper surface of the leaf, the phloem cells are under these, and above the xylem are stone cells, which are very hard and with contents high in silicon, making a mass impenetrable to the beaks of aphis.

Beneath, and more or less surrounding the phloem, are sclerenchyma cells. These are thick-walled cells, with their walls composed mainly of lignin. Underneath these may lie the starch sheath and perhaps a few parenchymous cells; then again under these is another group of stone cells, and next are the cells of the lower epidermis.

Aphis are mainly phloem feeders (4), and since most of the aphis feed upon the lower surface of the leaves, their beaks must penetrate through the lower epidermis and epidermal cells, or the stomata, then through the stone cells or, more likely, between bunches of stone cells, then consecutively through the following tissues: parenchyma, starch sheath, sclerenchyma, and finally into the phloem.

From the epidermis, epidermal hairs or spines may arise; and the aphis encounter difficulties in reaching the epidermis, or in moving around on the leaf, depending upon the size, thickness, and number of these hairs. H 109 is one of the varieties of cane which is more resistant to mosaic, and the fact that the leaves (especially the sheaths) are heavily covered with stiff, large hairs, may be the reason that it is so resistant; for the aphis become hopelessly lost and are unable to approach near enough to the epidermis to sink their beaks into the phloem.

Both the external and internal structure of a leaf show characters which may prevent aphis from inserting the beak and thus transmit mosaic, these characters are:

* By N. A. Cobb, 1906, Bull. 4, Div. of Path. and Physio. of H. S. P. A. Exp. Sta.

1. Number, size (thickness), and hardness of leaf hairs.
2. Distance between the vascular bundles and their corresponding stone and sclerenchyma cells.
3. The size of the groups of stone and sclerenchyma cells.
4. The distance between the phloem and epidermis.
5. The thickness and hardness of the epidermis.

Death Factors of Aphis

Ladybeetles, syrphid flies, lacewing flies, predaceous mites, humidity and fungi, all tend to reduce aphids in number.

By far the most important of these is the Australian ladybeetle, *Coclophora inaequalis,* which preys, in both the adult and larval stages, on aphis. Fungi kill off large numbers of aphis in damp weather and are at such times the most important death factor. Any one of the above factors may be at certain times the most important; but they usually work together, and it is only a matter of time before they get the upper hand on any bad outbreak of aphis. In cases of very bad outbreaks of aphis on corn, sorghum, or very young cane (especially seedlings), the writer recommends the following spray to be applied with a knapsack sprayer under the highest pressure possible:

Black-leaf 40, or Nicotine Sulfate	1 to 2 teaspoonfuls
Liquid soap (or Sopozon)	1 tablespoonful
Water	1 gallon

Field methods have already been worked out for the prevention of mosaic and are known on all the plantations, especially with reference to healthy seed selection and control of weeds. However, I would like to refer again to the time when weeds should be cut; namely, while they are young and before they have a chance to flower or form seeds, and care should be taken not to cut the cane with the weeds.

By far the most important means of reducing mosaic is through planting healthy seed pieces and by keeping the fields free from grass weeds. The Australian ladybeetle certainly does its work well, even though at times it may be a little late. It might be advisable in the future to import more ladybeetles; but this is not the case at present, for the predators we now have in Hawaii are quite adequate to cope with the situation, except in a few rare cases.

Summary

1. The same kind of mosaic may look entirely different on various hosts, i.e., different species of grasses or sugar cane varieties (8).
2. Mosaic characteristics vary greatly within the same species and varieties, such as corn and sorghum.
3. Or, the same species and varieties of grasses may have more than one kind of mosaic.

4. Transmissions were made between twenty-two different species and varieties of grasses through the use of the corn aphis as a vector. The evidence developed in these experiments indicates that these twenty-two grasses acquired the same kind of mosaic, but with different characteristics. Or the aphis transmitted more than one kind of mosaic.

5. Mosaic was transmitted between corn plants by the corn leafhopper. In many cases attempts at transmission were failures.

6. Corn aphis may transmit one kind of mosaic (7).

7. Corn leafhoppers may transmit a different kind of mosaic (7).

8. Or both of these insects may transmit more than one kind of mosaic.

9. The corn leafhopper transmitted mosaic only from corn to corn with one exception, which was probably an accident.

10. Mosaic is transmitted most easily in the winter and the plants "show up with clear cut cases of mosaic."

11. In the summer it is more difficult to transmit mosaic and the mosaic characteristics are usually indistinct.

12. The experiments indicate that mosaic is permanent throughout the life of the plant, but that it may become very poorly defined at times, and later very pronounced.

13. No one knows the causative agent of mosaic, so it is called a filterable virus.

14. Wingless aphis have great difficulty in crawling any distance, except on a flat, smooth, dustless surface.

15. Winged aphis may fly with the wind for miles and therefore are probably the main agents in the spread of mosaic.

16. Both winged and wingless corn aphis and corn leafhoppers transmit mosaic.

17. Cane aphis do not transmit mosaic in experiments.

18. Mosaic may be transmitted artificially by hypodermic injections, needle punctures, grafting, etc., but only with great difficulty and many failures.

19. Better control of mosaic may be attained by cutting grasses when they are young, before they flower, and care should be taken not to cut the cane at the same time. The weeds cut should be piled as far from growing cane as possible. If possible cover the weed pile with fine dust.

Literature Cited

(1) Brandes, E. W. 1919. The mosaic disease of sugar cane and other grasses. In U. S. D. A. Dept. Bull. No. 829.

(2) Brandes, E. W. 1920. Artificial and insect transmission of sugar cane mosaic. In *Journal of Agr. Res.*, Vol. XIX, No. 3, p. 131.

(3) Brandes, E. W. 1920. Mosaic disease of corn. In *Journal of Agr. Res.*, Vol. XIX, No. 10, p. 517.

(4) Brandes, E. W. 1923. Mechanics of inoculation with sugar cane mosaic by insect vectors. In *Journal of Agr. Res.*, Vol. XXIII, No. 4, p. 279.

(5) Brandes, E. W., and Klaphaak, Peter J. 1923. Cultivated and wild hosts of sugar cane or grass mosaic. In *Journal of Agr. Res.*, Vol. XXIV, p. 247.

(6) Kunkel, L. O. 1922. Insect transmission of yellow stripe disease. In *The Hawaiian Planters' Record*, Vol. XXVI, No. 2, p. 58.
(7) Stahl, C. F. 1927. Corn stripe disease in Cuba not identical with sugar cane mosaic. In Tropical Plant Research Bull. No. 7.
(8) Lyon, H. L. 1921. Three major cane diseases: mosaic, sereh, and Fiji disease. In Experiment Station, H. S. P. A., Bot. Ser. Bull., Vol. III, Part 1.

Glucose Determinations

By H. A. Cook and W. R. McAllep

Methods for the determination of reducing sugars are more varied and have been subject to more revision than probably any other method used in sugar laboratories. All of these methods are more or less empirical and most of them are subject to factors which may introduce considerable error in the results.

The method described by Eynon and Lane (1), using methylene blue as an internal indicator, is one of the most convenient methods that has come to the writers' attention. This method combines a high degree of accuracy with simplicity, rapidity and convenience.

This method was first extensively used in the Islands by H. W. Robbins at Oahu Sugar Company. The method with certain modifications and precautions, based on experience in this laboratory, has recently been described in *The Hawaiian Planters' Record* (2). The method with other minor modifications has been proposed for adoption as the official method of the Association of Hawaiian Sugar Technologists.

Before adopting the method in this laboratory it was thoroughly checked against known mixtures of glucose and sucrose of approximately the concentrations found in mill juices. This was done by both H. F. Bomonti and the senior author, and the method was found to give accurate results on these solutions. Since then it has been used in this laboratory extensively on juices in clarification and other investigations. The method has proved itself to be so satisfactory that it has been proposed as the official method of the Association.

Before bringing this proposal before the association it was found advisable to investigate a few points which had arisen in connection with the use of this method and which might affect the accuracy of the results secured by both this method and the regular Munson and Walker method. These questions resolved themselves largely to the manner of preparation of the sample before titration or treatment with the Soxhlet solution.

Preparation of Samples

The question of preparation of samples for analysis has received considerable study, but there still appears to be some conflicting opinion on the subject.

Clarification of Sample:

It is quite generally conceded that most sugar house products require clarification with neutral lead acetate to remove non-sugar reducing substances, although there appears some difference in opinion on this point. Meade and Harris (3) concluded from their experiments that lead acetate clarification was unnecessary in the products with which they were working. Norris and Brodie (4) working with Hawaiian molasses concluded that these products should be clarified with lead acetate.

The conclusion upon which the necessity of lead acetate clarification is based seems largely to rest upon the fact that higher results are secured if the reducing sugars are determined before clarification with lead acetate than are secured after clarification and subsequent removal of the lead. It had been the opinion of one of the writers that neutral lead acetate clarification was unnecessary. The only experimental data the writers were able to find which proved that the neutral lead acetate precipitate actually contained non-sugar reducing substances was that of Eynon and Lane (1). As there was no experimental evidence available to solve this question for Hawaiian products a series of tests were run to secure data on this point.

The effect of clarification with lead acetate was determined on six samples of final molasses so chosen as to represent different parts of the Islands and widely varying conditions of practice. Glucose was determined on these samples in two ways. Two portions of 10 grams each were weighed into 250 cc. flasks, and dissolved. The first portion made to volume, 50 cc. transferred to a 200 cc. flask, 10 cc. of 10 per cent potassium oxalate added, made to volume and filtered through Kieselguhr. The second portion was clarified with 3 cc. 54° Brix neutral lead acetate, and filtered. To 50 cc. of this filtrate in a 200 cc. flask, 10 cc. of 10 per cent potassium oxalate was added, made to volume and filtered. The final filtrates were used for the glucose determinations. Glucose was determined in triplicate. Potassium oxalate was used instead of disodium phosphate based on the conclusions of Eynon and Lane that lime salts gave low results. The results are as follows:

TABLE I

Sample No.	Treatment: Potassium Oxalate % Glucose	Treatment: Lead Acetate Potassium Oxalate % Glucose	Difference
1	11.089	10.789	.300
2	12.938	12.596	.342
3	20.935	20.450	.385
4	23.568	22.917	.651
5	16.005	15.743	.262
6	16.949	16.548	.401
7	11.325	11.020	.303

These figures all show decidedly lower results after treatment with lead acetate.

It is generally considered that neutral lead acetate does not remove appreciable amounts of reducing sugars from solution. Browne (5) gives figures show-

ing comparative amounts. Eynon and Lane (1) show that the amount of reducing sugar removed by neutral lead acetate is negligible.

The following test was designed to determine whether the substances which are removed from molasses by neutral lead acetate have reducing power. A large quantity of three of the above samples was treated with neutral lead acetate and filtered. The precipitate was washed with distilled water until a test with alpha-naphthol showed no reaction for sugar and then washed with an additional 3 liters of distilled water. The precipitate was then suspended in water, decomposed with hydrogen sulphide, filtered, washed and reprecipitated with neutral lead acetate. This precipitate was again thoroughly washed, suspended in distilled water, decomposed with hydrogen sulphide the second time, filtered and washed. It was again precipitated with neutral lead acetate and thoroughly washed with distilled water. This treatment entirely eliminated all sugar from the lead acetate precipitate.

The sugar-free precipitates secured were treated in three ways. One portion was treated with hot distilled water and filtered; a part of this filtrate was deleaded with disodium phosphate and the other portion freed from lead with hydrogen sulphide and the excess removed by boiling. These portions were added to Soxhlet solution and heated under the conditions of the glucose determination. Copper was reduced in both cases. (2) Another portion of the lead acetate precipitate was dissolved with dilute sulphuric acid and the lead removed by boiling down with the acid. The filtrate from this treatment, neutralized with NaOH, also reduced Soxhlet solution. (3) A third portion of the lead acetate precipitate was decomposed with hydrogen sulphide, freed from the excess by boiling and this filtrate also reduced Soxhlet solution. The precipitates from the three molasses were treated in this manner and all reduced Soxhlet solution when treated as above. A portion of the filtrate which had been treated with sulphuric acid (No. 2 above) and then neutralized, was added to a solution containing equal parts of pure dextrose and levulose, and the reducing power was determined before and after the addition with the following results:

Dextrose-Levulose Solution	.1844 gms. reducing sugar.
Ditto, plus filtrate	.1880 " " "

No definite amount of the precipitated substance was added to the pure solution, so the reducing power of the substances was not calculated. The reducing power of the pure solution was materially increased by the presence of the substances which had been precipitated from molasses by the neutral lead. A portion of this mixed solution was again treated with neutral lead acetate, deleaded with disodium phosphate and the reducing power again determined. The result was .1848, which agreed very closely with the original figure. From these tests the following conclusions were drawn:

(1) Neutral lead acetate removes organic non-sugar reducing substances from molasses.

(2) The substances removed by neutral lead acetate and freed from sugars reduce Soxhlet solution in the absence of other reducing sugars and increase the reduction in a pure dextrose or levulose solution.

(3) When freed from lead and added to pure solutions of dextrose or levulose these substances can again be removed by lead acetate and the original reducing power of the solution restored.

(4) The reducing substances removed from molasses by neutral lead acetate are sufficient to materially affect the results in a glucose determination.

Effect of Lime Salts on Glucose Determination

Eynon and Lane (1) have demonstrated that the presence of lime salts in the solution to be tested caused low results. They recommend that potassium oxalate be used instead of disodium phosphate as a deleading and decalcifying agent. This is the first reference that could be found showing the influence of lime on glucose determinations. Mead and Harris (3) secured higher results when using potassium oxalate as did Norris and Brodie (4), but this difference was not attributed to the removal of lime salts; they concluded that the potassium oxalate had a reducing action on the Fehling or Soxhlet solution.

Several series of tests were made to determine the above points and to determine the effect of lime and its removal on the determination of reducing sugars.

Does Potassium Oxalate Reduce Fehling Solution:

It was first determined whether potassium oxalate added to the Soxhlet solution in varying amounts in the absence of sugars would reduce copper. Various concentrations of the salt, from .5 gram to 20 grams per 100 cc., were added to the mixed Soxhlet solution and treated under the conditions that would apply to the glucose determination. In no case could reduction of copper be detected.

Varying amounts of a 10 per cent solution of potassium oxalate were then added to solutions of pure dextrose and levulose to determine whether any difference in the reducing power could be determined. The results are listed below.

TABLE II

	cc. Potassium Oxalate Added						
	Blank	2	4	5	6	8	10
	Grams reducing sugar						
Dextrose...	.1866	.1868	.1869		.1867	.1864	.1864
Levulose...	.1951			.1952			.1948
Levulose...	.1932	.1931	.1933		.1931	.1934	.1933

The above results are all practically constant and within the limits of experimental error. They show no change in the reducing power of either pure dextrose or levulose. Disodium phosphate was used in the same manner and no change in reducing power could be detected.

It can be concluded that in pure solutions neither potassium oxalate nor disodium phosphate influence the results of the glucose determination.

Lime in Pure Solutions:

The effect of adding lime salts to pure solutions was determined. For these determinations pure solutions of cane sugar and hydrolized cane sugar, also pure solutions of dextrose and levulose were used.

The first solution was a mixture containing 2 grams pure cane sugar and approximately .22 gram invert sugar. The invert sugar was prepared by hydrolysis of pure cane sugar with hydrochloric acid and then neutralizing with sodium hydroxide. To aliquot portions of this mixture varying amounts of different lime salts were added. No definite amount of lime was striven for in these solutions nor was the amount determined except that the solutions of lime were saturated solutions. The result of this test is tabulated below.

TABLE III

Sample	Treatment	Grams Found	Glucose Decrease
1	Pure sucrose and glucose blank	.223	....
2	" " " " 2½ cc. CaO	.217	.006
3	" " " " 5 cc. CaO	.209	.014
4	" " " " 10 cc. CaO	.202	.021
5	" " " " 25 cc. CaO	.196	.027
6	" " " " 2½ cc. $CaCl_2$	.221	.002
7	" " " " 5 cc. $CaCl_2$	.220	.003
8	" " " " 10 cc. $CaCl_2$	.216	.007
9	" " " " 25 cc. $CaCl_2$	.215	.008
10	" " " " 2½ cc. $CaSO_4$	.224	*.001
11	" " " " 5 cc. $CaSO_4$	.224	*.001
12	" " " " 10 cc. $CaSO_4$	.218	.005
13	" " " " 25 cc. $CaSO_4$	.212	.011
14	" " " " 2½ cc. $Ca_3(PO_4)_2$	.221	.002
15	" " " " 5 cc. $Ca_3(PO_4)_2$	.217	.006
16	" " " " 10 cc. "	.215	.008
17	" " " " 25 cc. "	.213	.010

In practically all cases the value found for glucose is depressed by increased amounts of lime. Similar results were secured with both dextrose and levulose solutions.

	No Lime	Lime Added	Decrease
Dextrose	.2001	.1981	.0020
Levulose	.1949	.1897	.0052

It is apparent that the presence of lime causes low results. Removal of lime with potassium oxalate was studied in another solution of sucrose and glucose. This solution contained approximately 4 grams of sucrose and .175 gram of glucose per 100 cc. This solution was divided into five portions. One portion was used as a blank, 25 cc. of each of the above lime solutions were added to the other portions of this solution. These portions were further divided and the glucose determined both in the presence of the lime salts and after treatment with 10 cc. of 10 per cent potassium oxalate.

* Indicates increase.

TABLE IV

Sample	Treatment	No Lime Present	With Lime Present	Difference Due to Lime Salts	Decalcified With Potassium Oxalate	Difference Between Original and Decalcified Portion
1	None	.176	....	......	....	......
2	CaO		.152	—.024	.173	—.003
3	$CaCl_2$		.169	—.007	.175	—.001
4	$CaSO_4$		.166	—.010	.173	—.003
5	Ca Phos.		.167	—.009	.175	—.001

A solution of pure dextrose and one of pure levulose was also prepared and treated in a similar manner.

TABLE V

	Blank	Lime Added	
	No Lime	Not Removed	$K_2C_2O_4$ Added
Dextrose.................	.2001	.1981	.1995
Levulose..................	.1949	.1897	.1947

All of these samples show the depressing effect due to the addition of lime. Treatment with potassium oxalate restored the reducing power to practically the original point.

The amount of lime in the above samples, except possibly those with the smaller amounts of calcium sulphate and calcium phosphate, was in excess of what would be found in sugar house products other than molasses. To approximate clarification practice aliquot portions of a juice were clarified by adding increasing amounts of milk of lime. The glucose was determined in these samples both before removing the lime and after treatment with potassium oxalate.

TABLE VI

pH of Cold Limed Juice	Per Cent Glucose Untreated Sample %	Per Cent Glucose Treated With Potassium Oxalate %	Difference
6.5	.188	.189	+.001
7.5	.187	.186	—.001
8.5	.187	.187	.000
9.5	.187	.187	.000

These results would indicate that the amount of lime present in this particular clarified juice was not sufficient to affect the results.

Another series was run to corroborate the above, Table VII. In this series the glucose was also determined by the regular Munson and Walker method, Table VIII. Four portions of a sample of raw juice were clarified at four different reactions. These samples were held at 100° C. for approximately three hours and the glucose was determined before and after heating. Table VII shows the effect of removing the lime salts both before and after heating.

TABLE VII

Methylene Blue Method

Sample	Lime Not Removed	$K_2C_2O_4$ Treated	Difference
	%	%	
1a	.754	.778	.024
1b	.939	.959	.020
2a	.675	.694	.019
2b	.787	.801	.014
3a	.748	.767	.019
3b	.768	.792	.024
4a	.767	.788	.021
4b	.749	.767	.018

The above figures show an appreciable and consistent difference between the untreated and the potassium oxalate treated portion. The portions treated with potassium oxalate gave results averaging .020 higher than the untreated portion.

In the following tabulation the figures are arranged to show a comparison of the results secured by using potassium oxalate in the methylene blue method with lead acetate and disodium phosphate in the Munson and Walker method. The Munson and Walker method was used conforming with the prescribed procedure of the official methods of the Association of Hawaiian Sugar Technologists, except that the amount of reduced copper was determined by titration with thio-cyanate solution rather than by weight as cupric or cuprous oxide. Titration with thio-cyanate has been shown to give more accurate results than the method of weighing.

TABLE VIII

Comparison of Results of Two Treatments

Sample	Potassium Oxalate No Lead Acetate	Lead Acetate and Disodium Phosphate	Difference
	% Glucose	% Glucose	
1a	.778	.725	.053
1b	.959	.912	.047
2a	.694	.648	.046
2b	.801	.766	.035
3a	.767	.723	.044
3b	.792	.745	.047
4a	.788	.745	.043
4b	.767	.726	.041

These figures show a very consistent difference in results between the two methods of treatment. The results given by the methylene blue method using potassium oxalate average .044 higher than those secured using disodium phosphate in the Munson and Walker method. Referring to the results in Table VII, it is noted that in determining glucose by the methylene blue method without lead acetate or potassium oxalate, the results average .025 higher than those secured by the Munson and Walker method, where lead acetate and disodium phosphate are used. Results which are shown later indicate that the above difference may be due to two factors. Lime which was not removed by the disodium phosphate undoubtedly accounts for a part of the difference, the lead acetate used in the

same procedure may remove reducing non-sugars and cause a part of the difference. Lead acetate was not used in conjunction with the potassium oxalate.

Another test was made to determine the respective amounts of lime removed by different methods of treatment. Four portions of a raw juice were clarified with increasing amounts of lime. Glucose was determined on each sample using the methylene blue method: first, with no treatment; second, adding 10 cc. of 10 per cent potassium oxalate; and third, clarifying with 3 cc. 54° Brix lead acetate and subsequent deleading, one portion with 10 cc. of 10 per cent disodium phosphate, and the other with 10 cc. of 10 per cent potassium oxalate. The CaO was determined on an ashed portion of each filtrate.

TABLE IX

	1		2		3		4	
Treatment	Glucose %	CaO %	Glucose %	CaO %	Glucose %	CaO %	Glucose %	CaO %
None	.874	.0013	.877	.0020	.880	.0022	.880	.0023
Potassium Oxalate	.879	.0003	.888	.0003	.877	.00025	.892	.0004
Lead Acetate and Disodium Phosphate	.872	.00045	.874	.00035	.876	.0011	.882	.0021
Lead Acetate and Potassium Oxalate	.871	.00035	.879	.0002	.876	.0005	.888	.0009

With one exception, treatment with potassium oxalate alone gives the highest figure for glucose; also, with one exception, this treatment gives the greatest elimination of lime. The determination of glucose without any treatment gives a figure slightly lower than that secured using only potassium oxalate. The results are lower when the juice is clarified with lead acetate. With one exception, lead acetate followed by disodium phosphate gives the lowest results.

Potassium oxalate in the presence of lead acetate gives a less complete removal of lime than potassium oxalate alone. This is probably explained by the formation of a double salt of calcium plumbate which is slightly soluble and does not completely precipitate out.

There does not appear a direct proprotional agreement between the amount of lime and the amount of glucose, but it is shown that the presence of lime depresses the results. The results also indicate that clarification with lead acetate influences the result of the glucose determination.

The results of the study on the effect of lime may be summarized as follows:

The presence of potassium oxalate or disodium phosphate does not affect the reducing power of pure solutions.

The presence of lime in pure solutions of reducing sugars depresses the results. Removal of the lime with potassium oxalate restores the original reducing power.

The presence of lime causes low results in the regular Munson and Walker method as well as in the methylene blue method.

The removal of lime from clarified juices causes higher results to be secured for glucose.

Potassium oxalate is more efficient than disodium phosphate in removing lime.

It is indicated that neutral lead acetate clarification influences the results of the glucose determination in probably two ways: (1), incomplete removal of lime by potassium oxalate in the presence of lead, or (2), incomplete removal of lead.

Effect of the Presence of Lead on Glucose Determinations

The preceding work shows conclusively that the presence of lime causes low results. It also shows that potassium oxalate is a more efficient agent in removing lime than disodium phosphate. Some irregularities in results seemed to indicate that potassium oxalate might not be efficient in removing lead from solution. It seemed necessary to determine the effect of lead on the results and probably an efficient means for its removal.

The effect of lead in the solutions was first determined. Neutral lead acetate was added in varying amounts to molasses and pure solutions. The precipitate formed in the molasses due to the lead acetate was filtered off before the glucose was determined. The results are shown in the following table:

TABLE X

Material	cc. Lead Acetate (54° Brix)							
	Blank	0.2	0.4	0.5	1.0	1.5	2.0	3.0
	Gram reducing sugar							
Cane Sugar and Hydrolized Cane Sugar	.2131				.1805			
Dextrose	.1999				.2001			
Dextrose	.1901		.1894			.1866		
Levulose	.1832		.1827		.1822		.1785	
Molasses	.1086	.1066		.1042	.1023			.1026

The presence of excess lead in the solution causes low results. The presence of a comparatively small amount of lead produced a marked change in the result on the above molasses.

A comparison of the results obtained using potassium oxalate and disodium phosphate was made on several samples of molasses. The comparisons were made as follows: The samples were weighed out, dissolved and clarified with 3 cc. of 54° Brix neutral lead acetate. One portion of the filtrate was treated with 10 cc. of 10 per cent disodium phosphate and the glucose determined by the regular Munson and Walker procedure, and by titration using methylene blue as indicator. Another portion of the lead acetate clarified filtrate was treated with 10 cc. of 10 per cent potassium oxalate and the glucose determined by titration with methylene blue indicator. The results are listed below.

TABLE XI

Sample	Munson & Walker Method %	Methylene Blue Method: Potassium Oxalate %	Methylene Blue Method: Disodium Phosphate %	Difference Between Potassium Oxalate and Disodium Phosphate
1	.....	10.793	10.534	.259
2	.....	11.02	10.79	.22
3	24.28	24.28	24.28	.000
4	19.97	19.90	19.86	.040
5	.....	10.736	10.586	.150
6	11.37	11.15	11.08	.07
7	13.96	14.25	14.16	.09
8	16.29	16.40	16.33	.07
9	10.74	10.78	10.74	.04

The agreement between the two methods of analysis and between disodium phosphate and potassium oxalate in the methylene blue method is good in samples 3, 4 and 9 of the above molasses. The agreement is not so good in the other six samples. The differences between the treatment with potassium oxalate and disodium phosphate range from 0 to .26.

The following results show that similar differences are obtained with the Munson and Walker method when the two deleading agents are used:

TABLE XII

Sample No.	Deleading Agent: Potassium Oxalate %	Deleading Agent: Disodium Phosphate %	Difference
1	11.61	11.37	.24
2	11.09	10.74	.35
3	16.30	16.34	—.04
4	11.06	10.74	.32

In all but one of the above samples the potassium oxalate gives the higher results. Judging from preceding work it is probable that most of the difference is due to the presence of lime salts. It was found in the study of the effect of lime salts that if the solution of molasses was made distinctly ammoniacal before the disodium phosphate was added the lime was quite completely removed.

The following tests were designed to determine whether all of the difference between the two deleading salts was due to the removal of lime. A sample of molasses was clarified with neutral lead in the usual manner. One portion of the filtrate was treated with potassium oxalate, one with disodium phosphate, and the third made alkaline with ammonia and then treated with disodium phosphate, the results are as follows:

1. Potassium Oxalate .... 11.08 % Glucose
2. Disodium Phosphate .... 10.74 "
3. Made ammoniacal then adding Disodium Phosphate 11.20 "

An examination of the filtrates upon which the above test was made showed that the portion treated with potassium oxalate contained no trace of lime, but that an appreciable amount of lead was present. The disodium phosphate treatment showed the absence of lead, but a large amount of lime, while the portion which was made alkaline with ammonia contained no lead and but a trace of lime. This indicates that if the reaction of the solution is adjusted to the proper point disodium phosphate will remove the lime as well as the lead. These tests also indicate that both lead and lime cause low glucose results.

The above results indicated that possibly an excess of potassium oxalate was being used and that in the presence of this excess, soluble double salts of lead or lime were being formed which were not removed and which influenced the results. In the regular method about 3 cc. of 54° Brix neutral lead acetate is used for the clarification of 10 grams of molasses. Approximately .12 gram of neutral lead acetate and 1 gram of potassium oxalate, per gram of molasses, are used in the above procedure.

The following test was planned to determine the proper amount of each of the two salts necessary to remove lead, lime, or both, from molasses clarified in the above manner. Ten times the regular amount of molasses was weighed out and a proportional amount of neutral lead acetate was used for the clarification. Aliquots of this filtrate were measured out; one series was treated with potassium oxalate and the other series with disodium phosphate in amounts ranging from .01 gram to 3 grams per gram of molasses or per .12 gram of lead acetate. The lead and lime were determined qualitatively to determine the effective amount required for the most complete removal. The results are as shown below.

TABLE XIII

Grams Reagent	Potassium Oxalate		Disodium Phosphate	
	Lime	Lead	Lime	Lead
.01	Appreciable	Considerable	Considerable	Appreciable
.02	"	"	"	"
.04	"	"	"	"
.06	"	Appreciable	"	"
.08	"	"	"	"
.10	Decided Trace	Decided Trace	"	Decided Trace
.30	Slight "	Trace	"	Slight "
.50	None	"	"	None
1.0	"	Decided Trace	"	"
2.0	Trace	Appreciable	"	"
3.0	"	"	"	"

Potassium oxalate: When less than 0.1 gram is used appreciable quantities of both lead and lime remain in solution. The lime is quite completely removed with from 0.1 gram to 1.0 gram of potassium oxalate. Appreciable traces of lime again appear in the filtrate when more than 1.0 gram is used, the amount increasing as the concentration of potassium oxalate becomes greater.

Disodium phosphate: At the normal reaction of molasses disodium phosphate is not effective in removing lime. Lead is not completely removed with less than 0.1 gram; with 0.3 gram, or more, the lead is quite completely removed.

It was suggested that a mixture of the two salts might be better than one alone. This was tried in the following concentrations: 2 grams potassium oxalate with 8 grams disodium phosphate, and 3 grams potassium oxalate with 7 grams disodium phosphate per 100 cc. A qualitative test showed that the solutions treated with 10 cc. of either of these mixtures, contained neither lead nor lime.

A test was made to determine the effect of the above findings on glucose determinations. Three solutions were used. The first was a mixture of equal parts by weight of dextrose and levulose to which was added neutral lead acetate in amount equivalent to that used for molasses. Three molasses samples were used, clarified in the usual manner. The dextrose-levulose solution and the molasses filtrates were treated with varying amounts of potassium oxalate within the limits shown by the above test to be most efficient in removing both lead and lime.

TABLE XIV

Treatment	Dextrose and Levulose gms. Glucose	No. 1 Molasses % Glucose	No. 2 Molasses % Glucose	No. 3 Molasses % Glucose
Blank, no lead, .2 gm. Potassium Oxalate	.1949	23.237	20.641	11.293
Blank, lead not removed	.1834	......	......	......
Gm. Potassium Oxalate				
.05	.1889	......	......	10.341
.10	.1940	22.738	19.912	10.352
.20	.1947	22.851	20.299	10.771
.30	.1948	22.716	20.398	10.845
.40	.1947	22.763	20.426	10.770
.50	.1946	22.793	20.426	10.770
.60	.1943	......	......	10.845
.2 gm. Potassium Oxalate, .8 gm. Disodium Phosphate	.1948	22.948	20.456	10.968
.3 gm. Potassium Oxalate, .7 gm. Disodium Phosphate	.1947	22.899	20.451	10.971

The glucose results agree well with the results shown for the amounts of lead and lime present under the conditions of treatment. The figures for the pure dextrose and levulose mixture are practically constant and within limits of experimental error for amounts of potassium oxalate between .2 and .5 gram. A slight depression is indicated at .6 gram. The results with the two mixtures agree with those for potassium oxalate between .2 and .5 gram.

On molasses the results agree well between themselves, using amounts of .3 to .6 gram of potassium oxalate; with less than .2 gram, the results are all low. Also with less than .2 gram of potassium oxalate there were present traces of lime and appreciable amounts of lead. Between the range of .2 gram and .6 gram of potassium oxalate, lime was almost entirely absent, but there were present small traces of lead. It was deemed unnecessary to go beyond the limits given in the above table as preceding results had proved that the presence of lime or lead caused low results.

With the mixtures of the two salts the glucose results on the molasses are in good agreement but somewhat higher than those secured using potassium oxalate alone. Also the removal of lead and lime was more complete using the mixtures.

Further variations of the mixtures were tried on one sample of molasses. These mixtures consisted of 5 grams, 7 grams and 10 grams of each salt per 100 cc. The determinations were made on a separate weighing of the sample, so comparisons within minute quantities cannot be made directly with the above results. However, the results were in perfect agreement between themselves, and the filtrates showed complete removal of both lead and lime.

Under the conditions of the analytical procedure, the preceding tests show: (1) that both lead and lime depress the glucose results; (2) that disodium phosphate is efficient in removing lead, but does not satisfactorily remove lime; (3) that potassium oxalate removes lead and lime satisfactorily only within very narrow limits, more or less than the correct amount, leaves both in solution; (4) that a suitable mixture of the two salts removes both lead and lime satisfactorily.

Summary

1. Clarification with Lead Acetate:
   a. Neutral lead acetate removes organic non-sugar reducing substances from molasses.
      (1) The reducing substances removed from molasses are sufficient to materially affect the results in a glucose determination.
      (2) The substances removed by neutral lead acetate reduce Soxhlet solution in the absence of other reducing sugars and increase the reduction in a pure dextrose or levulose solution.
      (3) When freed from lead and added to a pure solution of dextrose or levulose these substances can be again removed by lead acetate and the original reducing power of the solution restored.
2. Lead causes low results and must be removed:
   a. The presence of lead depresses the reducing power of pure dextrose and levulose.
   b. The original reducing power is restored by removal of the lead.
   c. The presence of lead causes low results in raw or clarified juice, syrup, raw sugar solutions and molasses.
3. Lime causes low results and must be removed:
   a. The depressing effect upon the reducing power has been demonstrated in juice samples, molasses, pure hydrolized cane sugar, and in pure dextrose and levulose solutions.
   b. The original reducing power is restored by removal of the lime.
4. Deleading and decalcifying agents:
   a. Disodium phosphate.
      (1) Completely removes lead from sugar solutions.
      (2) Removes only very small amounts of lime from sugar solutions unless the solutions are made quite alkaline in reaction.
      (3) When lead acetate and lime are added to sugar solutions the addition of disodium phosphate does not restore the original reducing power.
      (4) An excess of disodium phosphate does not influence the results.
   b. Potassium oxalate.
      (1) Used in proper quantity completely removes lime from sugar solutions.
         (a) When lime is added to pure sugar solutions the removal with potassium oxalate restores the original reducing power.
      (2) Used in proper quantity removes all but traces of lead.
         (a) The reducing power of sugar solutions to which lead and lime have been added is restored when the proper amount of potassium oxalate is used.
         (b) In the presence of lead either a deficiency or an excess of potassium oxalate leaves lead and lime in solution and causes low results.
         (c) In the absence of lead an excess of potassium oxalate does not influence the results.

c. Mixture of potassium oxalate and disodium phosphate.

(1) A mixture of the two salts in the proper amount satisfactorily removes both lead and lime from sugar solutions.

(a) Pure solutions to which lime and lead salts have been added, have the original reducing power restored when treated with the mixture.

(2) The proposed mixture for the method of analysis is: 3 grams potassium oxalate ($K_2C_2O_4$) and 7 grams disodium phosphate ($Na_2HPO_4.12H_2O$) in 100 cc. of distilled water.

(3) A mixture of the salts extends the range in which lead and lime are completely removed; a moderate excess of the oxalate under these conditions does not retain lead in solution as when used alone. The permissible excess which can be used in this manner is subject to further investigation.

5. Proposed methylene blue method for glucose determination:
The method as described in the *Record* (2) and reprint therefrom to be used with the following exceptions:

a. Preparation of samples: The concentration of glucose in the prepared sample should be such that 15 to 45 cc. of the solution, corresponding to 116 to 335 mgs. glucose per 100 cc. is required for titration. Preferably the amount should be from 25 to 40 cc. or 125 to 200 mgs. glucose per 100 cc.

(1) Juices: For control purposes the juices should be clarified with the smallest possible amount of neutral lead acetate, and an aliquot of the clarified sample treated with 10 cc. mixed oxalate-phosphate solution and again filtered with Kieselguhr. The filtrate is used for the titration. For agricultural or field work, the error due to the non-sugar reducing substances in juices would be small and lead acetate clarification could be omitted, also the amount of lime in the raw juice would be slight, the combined effect of these salts would be small, so that an aliquot of the juice after Kieselguhr filtration could be titrated direct.

(2) Molasses: 10 cc. of the mixed oxalate-phosphate solution substituted for disodium phosphate after neutral lead acetate clarification.

(3) Syrup and raw sugar: The procedure for glucose determination would be similar to that for molasses.

b. Analysis: To be made as previously described, with whatever further details may be necessary.

c. Calculations of results: To be made as described. An addition to the published table of factors may be advisable for use with syrup and raw sugars.

The above summary of this work was presented at the meetings of the Association of Hawaiian Sugar Technologists, October 17 to 20, 1927, with a proposal that the methylene blue method be adopted by the Association as the official

method for glucose determinations. The method was recommended for adoption on the basis of experience with the method in this laboratory and on the work which is presented herewith. This work had been completed but a few days before the meetings, so that a detailed report was not possible at that time.

It is proposed that the committee appointed for this purpose draw up a detailed procedure for the determination of glucose based on the above findings; that the method set forth definite specifications for the amount of neutral lead acetate to be used for the clarification of the sample and also the amount and nature of deleading and decalcifying agent.

Methods for the determination of glucose do not specify the amount of neutral lead acetate to be used for clarification of the products, but state, "clarify with neutral lead acetate, avoiding an excess." Experience in this laboratory, covering a large variety of juices and molasses from practically all plantations in the Islands, indicates that 3 cc. of 54° Brix neutral lead acetate is sufficient for the clarification of 10 grams of molasses, and that 1 cc. is sufficient for mill juices and raw sugar. For this amount of lead acetate a definite mount of deleading and decalcifying agent should be specified. If such a specification is made we believe that the phosphate-oxalate mixture proposed will satisfactorily remove both lead and lime from the solution, thus avoiding the errors due to their presence.

Acknowledgment

The writer wishes to extend acknowledgment to Dr. F. E. Hance for valuable suggestions in the treatment of the lead acetate percipitate from molasses.

Literature Cited

(1) Lane, J. Henry, and Eynon, Lewis. 1923. Determination of reducing sugars by means of Fehling's solution with methylene blue as internal indicator. *Jr. Soc. Chem. Ind.*, pp. 32T, 143T, 463T.

(2) McAllep, W. R. 1926. Methylene blue method for glucose determination. *The Hawaiian Planters' Record*, Vol. XXX, p. 461.

(3) Meade, George P., and Harris, Joseph B. 1916. The gravimetric determination of reducing sugars in cane products. *Jr. Ind. & Eng. Chem.*, Vol. VIII, p. 507.

(4) Norris, R. S., and Brodie, A. 1917. Report of committee on glucose determinations. *The Hawaiian Planters' Record*, Vol. XVII, p. 311.

(5) Browne, C. A. 1912. *Handbook of Sugar Analysis*, p. 216.

Sugar Prices

96° Centrifugals for the Period September 16 to December 15, 1927

Date		Per Pound	Per Ton	Remarks
Sept.	16, 1927......	4.86¢	$97.20	Cubas.
"	19...........	4.83	96.60	Cubas.
"	23...........	4.77	95.40	Cubas.
"	27...........	4.74	94.80	Cubas.
Oct.	3...........	4.71	94.20	Cubas.
"	4...........	4.65	93.00	Philippines.
"	10...........	4.565	91.30	Cubas, 4.55; Philippines, 4.58.
"	11...........	4.65	93.00	Cubas.
"	13...........	4.71	94.20	Cubas.
"	18...........	4.65	93.00	Cubas.
"	21...........	4.665	93.30	Cubas, 4.68, 4.65.
"	25...........	4.71	94.20	Porto Ricos.
"	26...........	4.68	93.60	Cubas.
"	31...........	4.65	93.00	Cubas.
Nov.	2...........	4,58	91.60	Cubas.
"	9...........	4.65	93.00	Cubas.
"	14...........	4.71	94.20	Cubas.
"	18...........	4.65	93.00	Cubas.
"	28...........	4.58	91.60	Cubas.
"	30...........	4.52	90.40	Cubas.
Dec.	8...........	4.58	91.60	Cubas.
"	10...........	4.61	92.20	Cubas.
"	12...........	4.58	91.60	Cubas.
"	14...........	4.595	91.90	Cubas, 4.58, 4.61.
"	15...........	4.61	92.20	Cubas.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXII. APRIL, 1928 Number 2

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

P. O. J. 2878

The photograph on the cover indicates the excellent growth which this cane has been making in the quarantine house, in spite of the cool weather during the past months.

Its long, drooping leaves and robust top give it an impressive appearance. It is ahead of a stool of H 109 of about the same age.

Its mother is P. O. J. 2364, a seedling of P. O. J. 100 x Kassoer, and is not itself a commercial cane. Its father, E. K. 28, was the leading cane in Java from 1920 until the present year, when it was obliged to give way to its vigorous offspring.

P. O. J. 2878 was germinated at the Java station in 1921. Seed was distributed to plantations in 1923. By 1925, the results of twenty-six yield trials on different plantations had been reported to the Station. In nineteen of these, P. O. J. 2878 outyielded the standard variety with which it was compared.

In 1926, it had been spread to ¾ per cent of the total acreage in Java; in 1927, to 12½ per cent, and in the present crop to 66½ per cent. It now occupies over 300,000 acres in Java. It is reported to be making a good showing in the Philippines also.

Hawaiian Seedlings—1928 Propagation

The newly propagated seedlings at the Experiment Station this year offer unusual interest. The lot of over 50,000 is made up of over 300 different crosses of known parentage. These include 2,200 seedlings of Kassoer blood. About 1,700 include Kassoer and Yellow Caledonia, a unique combination in sugar cane breeding. There are in all about 5,000 Yellow Caledonia seedlings, a number many times greater than in any previous year. Also, there are approximately 800 Uba hybrids (including the Natal, Porto Rico, and Hawaiian strains) crossed for the most part with H 456. In seedlings of P. O. J. 213 and P. O. J. 234, we have Chunnee quarter-breeds. Finally, it may be said that the Hawaiian-grown seedlings of P. O. J. 2364 (the mother of P. O. J. 2878) carrying Yellow Caledonia blood hold special promise in a season's production which on the whole offers high expectations.

The Retention of Nitrates by Hawaiian Soils

By Guy R. Stewart and Fred Hansson

Since fertilizers were first used upon Hawaiian cane land, the application of nitrogenous salts has given consistently large increases in the yield of cane and sugar. The nitrogen content of either mixed fertilizers or simple salts always represents the greatest money value in the amount expended for fertilizing materials. This does not mean that we are inclined to underestimate the importance of a balanced system of fertilization which supplies adequate amounts of potash and phosphates, as well as nitrogen, at an early stage of the growth of the crop. The experimental evidence which is being obtained by this Experiment Station, and the various plantations in general, indicates the importance of a supply of available nutrients for the young cane plant as soon as it has started active development. But we are especially interested in the matter of nitrogen economy in fertilization, both on account of the large return given by the proper use of this nutrient and by the large percentage of our fertilizer cost which is represented by this one ingredient.

The writers have accordingly carried on several field tests upon the retention of nitrates under field conditions in order to try to obtain some experimental evidence of the conditions prevailing. This work has been carried out with the cooperation of George F. Renton, manager of Ewa Plantation, and W. P. Alexander, agriculturist of that plantation.

In the early reports of Maxwell (6) upon the soil investigations carried out at this Experiment Station there is considerable discussion of the retention of nitrogenous salts in soils. As a result of lysimeter tests upon short soil columns, and field observations which showed the rapid movement of water through the more porous soil types, Maxwell advised against the use of nitrate of soda in regions of heavy rainfall or where heavy irrigation was the usual practice. He believed there was a large loss of nitrogen where soluble nitrates were applied, and strongly urged that ammonium sulfate should be applied where there was a possibility of the loss of nitrogen by leaching.

Later field experiments carried out by the agricultural department of this Station and by a number of plantations have shown that excellent increases in cane tonnage were obtained through the use of nitrate of soda as a supplementary source of nitrogen to augment the amount supplied by mixed fertilizers. It should be pointed out that approximately one-third to one-half of the nitrogen content of the mixed fertilizers is derived from nitrate of soda. A study of the factors affecting the retention of nitrate nitrogen is therefore of decided interest in estimating the return from the manurial treatments applied to the Island cane lands.

The senior author has previously shown (10) some evidence of the retention of nitrates in four-foot soil columns of several typical Island soils upon which no

crop was being grown. When heavy irrigations were applied to soil columns which had been fertilized with nitrate of soda, the loss of nitrates from the four-foot columns was very small with the first two irrigations. Later irrigations carried down a portion of the added nitrates into the third and fourth foot of soil and carried away variable amounts of nitrates in the drainage waters. The quantity of nitrates lost in the drainage varied with the soil type. With the most retentive soil there was no loss of added nitrate above the amount of nitrate nitrogen leached out of an unfertilized soil. In the case of less retentive soils the total loss of added nitrogen ranged from 25 to 35 per cent of the amount put on.

Peck (8) has previously carried out a series of lysimeter studies, with shorter soil columns, using several typical Island soils. There was some evidence of the retention of nitrates in his results. This soluble form of nitrogen was not washed out of the soil with the rapidity which might be anticipated.

There are several factors which might influence the retention of nitrates in a soil, but the most important of these is the power of adsorption which colloidal particles possess. In the early study of colloids, the attempt was first made to distinguish between soluble materials such as potassium sulphate or sodium chloride, which were called crystalloids, and bodies, such as starch or glue, which were called colloids. This distinction is no longer made. It is now known that a large number of materials can exhibit colloidal properties if they are in a sufficiently finely divided condition. These colloidal properties depend primarily on the small size of the ultimate particles of the colloid. A large number of the materials which are most commonly used in ordinary life depend for their value upon the colloidal nature of the particles composing the substance. Prominent among such colloidal products are milk, paints, mayonnaise, glue, starch, ink, bread dough, and innumerable other materials which are handled in everyday life.

An important colloidal property is the ability which finely divided solids possess to adsorb varying amounts of soluble salts from solutions passing through the solid so that the solution which has passed down through such a colloid contains less of the soluble salt than was originally present. This phenomenon of adsorption is largely a physical phenomenon, though certain of the ions of the salts present in a solution may actually react with the colloidal particles.

Our Island soils have a comparatively high content of colloids. These are the finely divided clay-like and silty portions of the soil which give the volcanic soils their characteristically open, spongy texture.

Besides these inorganic colloids, our Hawaiian soils all contain more or less organic colloidal material, which has accumulated in the soil as a result of the decomposition of plant residues. The physical state of these inorganic and organic colloids will have a tremendous effect on the permeability of a soil. The investigation of Hissink (3), Gedroiz (1), Kelley (4), have shown clearly that the finely divided colloidal material of the soil possesses the property of reacting with cations such as calcium, magnesium, sodium ammonium and potassium. This subject of the effect of these replaceable bases on the soil structure was discussed in some detail by Hance and the senior author (2) in the October *Record*. We shall only point out at this time that normal agricultural soils which are in good physical condition and are permeable to air and water, ordinarily contain appreciable quantities of re-

placeable calcium which is held by the colloidal portion of the soil. We have found that puddled, deflocculated Island soils may be caused by an excessive quantity of replaceable sodium or magnesium which has displaced the calcium, which should be present in the soil colloid. The opinions of investigators of the phenomena of base exchange differ as to whether it is a chemical reaction or an adsorption effect. A great deal of evidence indicates that base exchange partakes of the nature of a chemical reaction. It is at least evident that the cations or basic radicals of a fertilizer salt may be fixed in the colloidal complex of the soil if the particular cation is present in greater amount than the soluble calcium of the soil solution. Should the cation be fixed in the soil colloid it will displace an equivalent amount of replaceable calcium. The displaced calcium and the ion, which was formerly combined with the displacing base of the fertilizer salt, would tend to be carried directly out of the soil in the drainage water, were it not for the adsorptive power of the fine particles of the soil colloid.

In the case of nitrate of soda, if this salt is applied to the soil, it will go into solution as soon as it comes in contact with rain or irrigation water. This will make a very dilute solution which will pass down into the soil solution. If the amount of nitrate of soda present in the soil solution is sufficiently small the salt will ionize or separate completely into sodium ions and nitrate ions. Where the sodium ion is present in greater proportion than calcium in the soil solution, the sodium ion or basic radical will tend to displace an equivalent amount of calcium. Where the soil solution contains an excess of soluble calcium the replacement by sodium will be very slight. The nitrate ion would tend to pass directly out of the surface soil and be carried away in the drainage water were it not for the adsorptive effect of the finely divided particles of the soil colloid. This adsorption is likely to be sufficiently great in our colloidal Island soils so that the nitrate radical and the base associated with it will be partially removed from the soil solution. The drainage water passing out of the soil will always contain some nitrates, but we have good theoretical grounds for believing that the amount of nitrates lost in the drainage water will be appreciably less than the amount originally present in the surface soil.

The effect of colloidal adsorption in retaining soluble salts will not be a permanent one. Later irrigations or rains may tend to carry away part of the adsorbed salts, but the extraction of nutrients by the plant roots has been shown by the senior author and others to occur at an early stage of growth in cereal crops (9). There is, therefore, every reason to believe that even a temporary adsorption of fertilizer salts will greatly increase the economical use of nitrogenous salts.

Experimental evidence of the adsorption of nitrate of soda by colloids is given by the work of Osaka (7), where he studied the relative adsorption of potassium iodide, potassium nitrate, sodium nitrate, potassium chloride, sodium chloride, potassium sulfate and sodium sulfate by blood charcoal. In the case of this blood charcoal no base replacement could take place. Retention of the salts could only be due to adsorption. Osaka found that the order of retention of the above salts was in the order above listed, that is, potassium iodide was most adsorbed, followed by potassium nitrate and then sodium nitrate.

It is very probable that the retention of a salt by adsorption will vary greatly with different soils. Differences in colloidal content between individual soils will, of course, be an important factor, but the relationship of the various salts present in the soil solution will also exercise an appreciable influence. This is clearly shown by the work of Lachs and Michaelis (5), among others, upon the adsorption of combinations of salts by charcoal. In some cases the addition of a second or third salt notably increased the adsorption, while in other instances it was decreased.

The above resume is not intended to be exhaustive, but merely gives some of the theoretical considerations involved in the study of the retention of fertilizer salts by soils.

Experimental Work

The experiments so far conducted in the field have been carried on at intervals in a period extending over several years. The work reported here has been done upon several different types of soil at Ewa Plantation. The following three fields were used in our first experiments: Field 6, where the surface soil is a brown, silty clay loam, underlain by a deep brown clay loam subsoil; Field 22, which has a red silt loam soil, underlain by a coral rock at a depth of 16 to 24 inches; Field 26, where the surface soil was a brownish black clay adobe, underlain by an even more compact clay subsoil. In the third and fourth foot of this subsoil there was a considerable amount of gypsum crystals, which would indicate that this soil had been deposited in a tidal flat, which was later isolated from the ocean, and subsequently elevated.

In our experiments in these fields, the cane grown was the H 109 variety, which was about six months of age. A uniform plot of land was chosen and a series of twelve surface soil and subsoil samples were taken at each sampling by means of soil augers. Each boring in Fields 6 and 26 was taken to a depth of four feet, each foot being kept separate and analyzed for moisture, nitrate nitrogen, ammonia nitrogen and nitrite nitrogen. In Field 22 the same procedure was followed, except that sampling could not be carried below 16 inches to 24 inches in depth.

After the preliminary samples were collected, sodium nitrate was applied at the rate of 650 pounds per acre, which supplied 100 pounds of nitrate nitrogen per acre. The plots were then irrigated and soil samples were collected in the same manner as the preliminary set. After each set of samples was taken, care was exercised to fill all the sample holes tightly with earth, in order to prevent subsequent irrigations from running down, through these holes, into the lower soil. In these preliminary studies we did not carry out observations upon an unfertilized plot, owing to lack of analytical assistance. This was done, however, in a later study in Field 1 C, and the results upon the movement of nitrogen are so similar that we believe we are justified in drawing certain general conclusions from the earlier experiments.

In order to make the voluminous analytical results available for ready study we have averaged the figures obtained upon the twelve separate samples for each foot of soil at each period of sampling. The results for ammonia nitrogen showed only traces were present at any time and there were no significant variations

throughout the experiments. We have, therefore, omitted the reproduction of these results. Small but determinable amounts of nitrites were found in all the soils, but here again the figures were practically constant, so we have omitted those data, which were not found to be significant. The data submitted cover the moisture determinations, nitrate nitrogen and soil reaction, expressed as pH. We shall consider the results for each separate field briefly and then summarize the more outstanding observations.

Field 6: The results cover two fertilizations, one in the late summer and another the following spring. The first fertilization, with 100 pounds of nitrogen per acre derived from nitrate of soda was made August 15. The field was irrigated the following day and then received water at approximately two-week intervals, eight irrigations in all up to November 22, the period covered by our fall observations. The determinations of moisture and nitrogen at each sampling period are given in Fig. 1. It will be seen that the increase of nitrates and moisture is greatest in the first and second foot of soil. There is a slight increase in the third foot and very

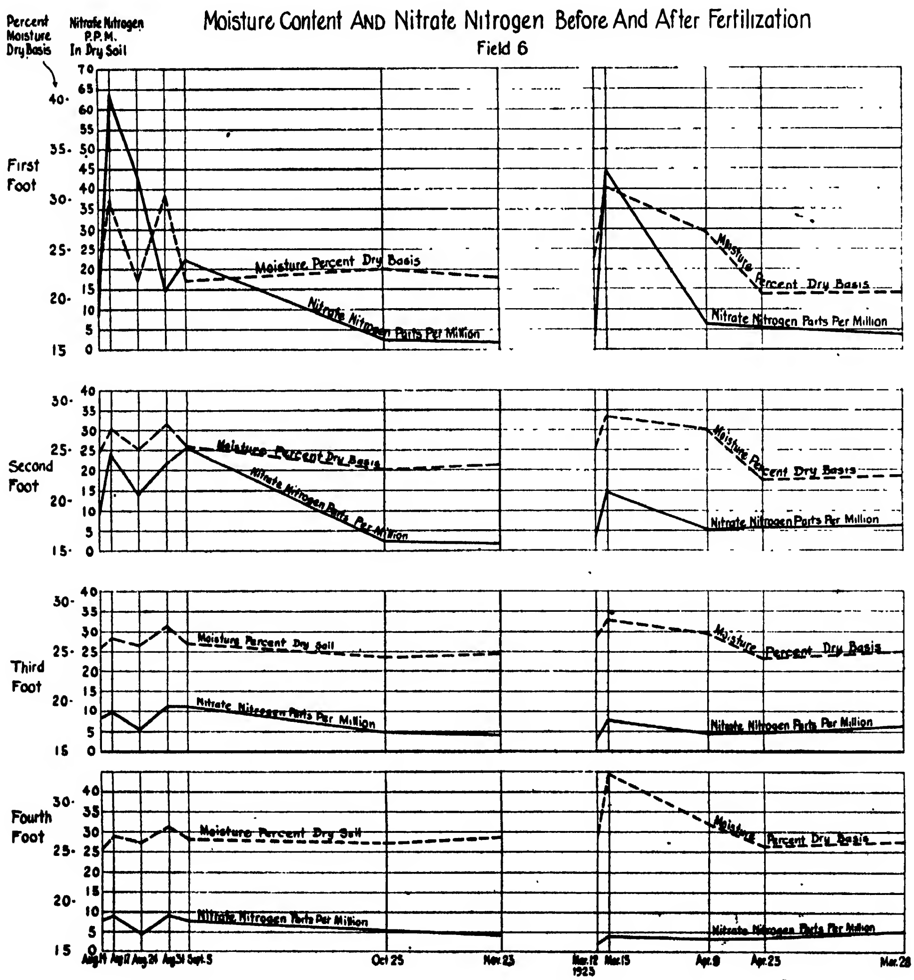


Fig. 1

little change in either constituent in the fourth foot. Our results show that in this experiment both nitrates and moisture were largely retained in the top two feet of soil. The increase of both moisture and nitrates is quite comparable, so we can not state that there was any definite evidence of adsorption or retention of nitrates out of the descending moisture. In the second fertilization, however, there was a greater increase of moisture than of nitrates in the lower soil strata. We are, therefore, inclined to believe that adsorption of nitrates has taken place. The period in which the cane crop reduced the nitrate content of the soil to the same level which prevailed before fertilization was about 10 to 12 weeks after the first fertilization, and a still shorter time elapsed before this happened after the second fertilization.

Field 22 C: The experiment in Field 22 C was started at the same date as Field 6. The subsequent irrigations were slightly less frequent, so that only six applications of irrigation water were made in the period from August 13 to November 22. The determinations of moisture and nitrate nitrogen are given in Fig. 2.

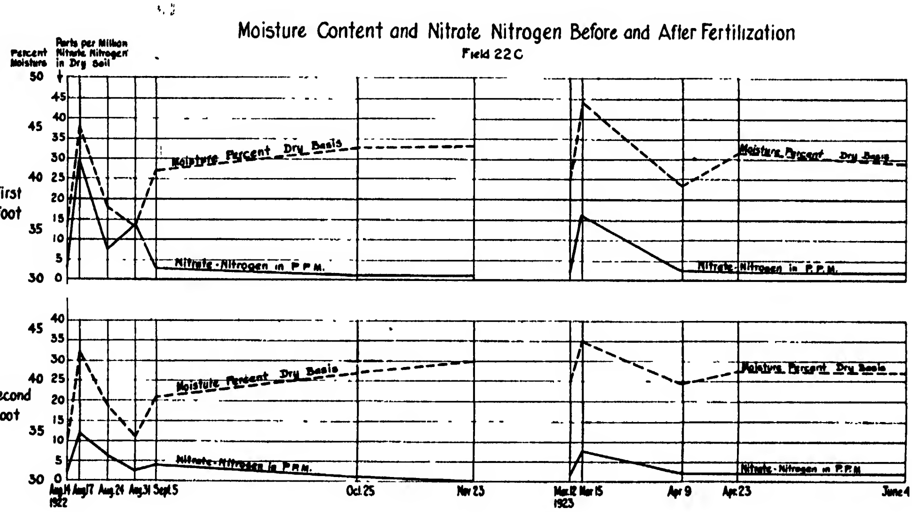


Fig. 2

In this soil there was a smaller increase of nitrates in the second foot than in Field 6 and there was a larger proportionate increase in moisture content in the second foot of soil. This would indicate some adsorption of nitrates in both periods of fertilization. In this shallow soil the nitrates were reduced to the low content which had prevailed before fertilization in a surprisingly short period of time after fertilization. In the fall period about 8 weeks elapsed before the added nitrates were removed, while in the second period the results indicate that only a month had elapsed until the nitrates were reduced to a low content.

Field 26: In this field the first application of 100 pounds of nitrogen per acre was made September 15. The nitrates were reduced to the previous level in about 8 weeks. After the spring fertilization, the added nitrates had disappeared from the soil in a still shorter time. In both cases, as shown in Fig. 3, there is some

evidence of the adsorption of nitrates by the upper layers of this heavy colloidal soil.

Field 1 C: This experiment was designed especially to study the course of nitrate retention in the soil under the growing conditions of the winter season. The control or X plots received no fall fertilization, while the N plot received a fertilization with 100 pounds of nitrogen per acre, derived from nitrate of soda,

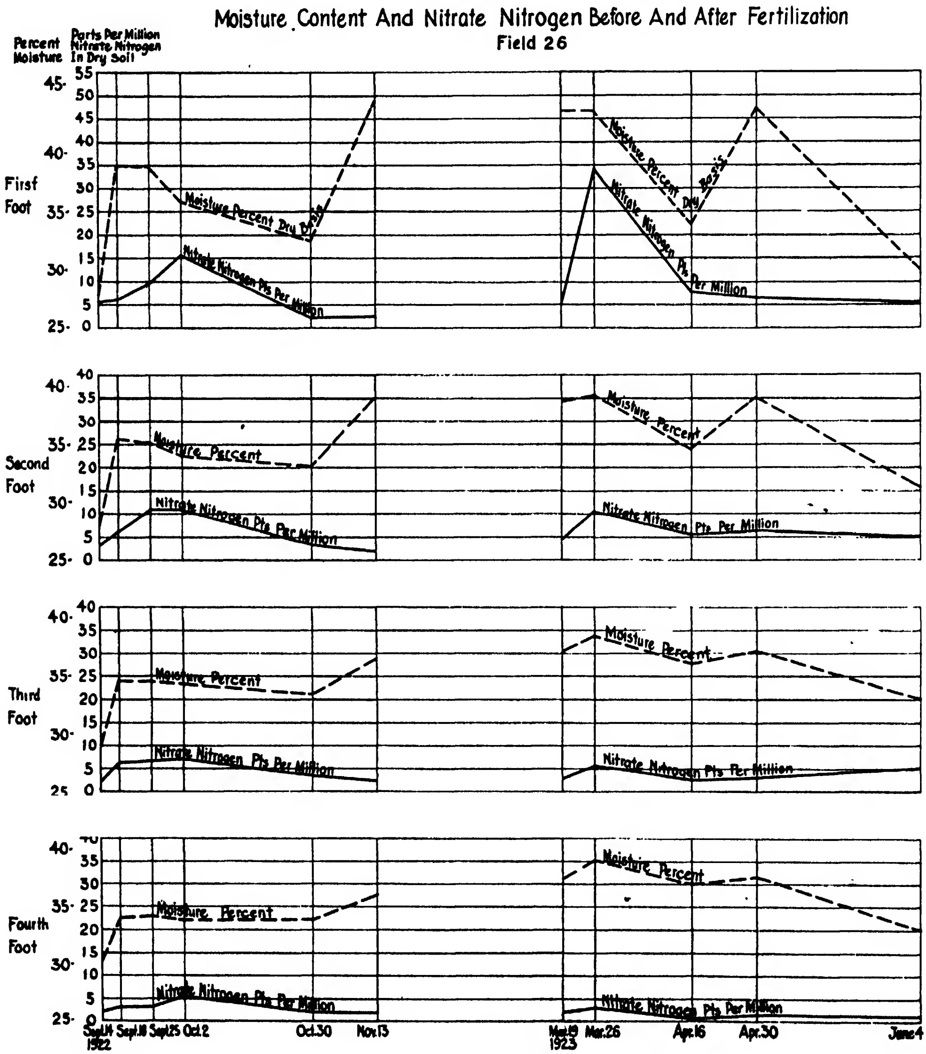


Fig. 3

on November 10. The plots used in this experiment formed part of the overhead sprinkler experiment installed in Field 1 C. The nitrogen was applied by hand and was then followed by a regular irrigation through the sprinkler system. Moisture, nitrates, and soil reaction were determined at frequent intervals throughout the winter months, and the following summer. The X plots received no nitro-

gen until the following spring. On February 11 both the fall fertilized and X plots received 53 pounds of nitrogen per acre. The nitrogen was derived from nitrate of potash and was applied through the sprinkler system, being followed by an after irrigation to wash the soluble nitrates off the cane leaves. A second fertilization of 74 pounds nitrogen per acre, derived from potash nitrate, was applied to both plots on April 1. This was also applied in the irrigation water.

The results of the comparative moisture determinations are given in Fig. 4. It is interesting to note that the soil of the plots receiving the fall fertilization at

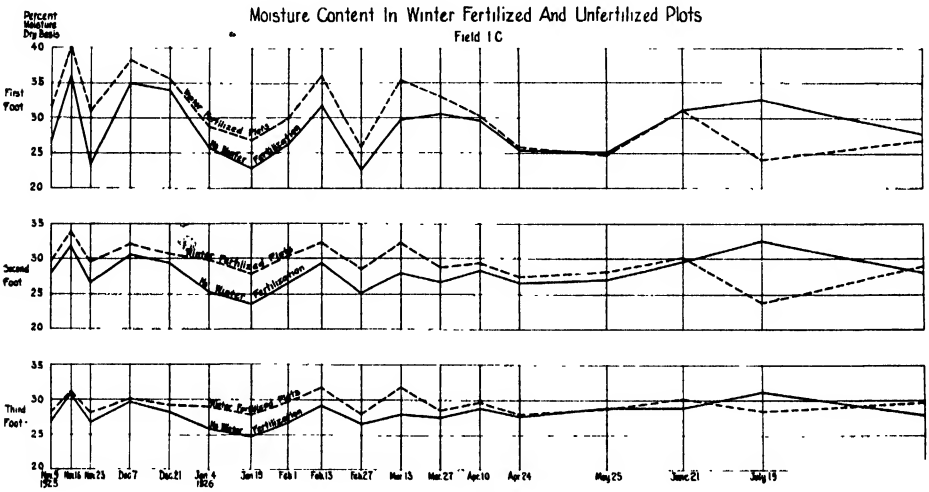


Fig. 4

all times showed a higher moisture content, until after the second spring fertilization. This agrees with the observations made by the senior author (11) in a study of the moisture content of fertilized and unfertilized plots of pineapples, both with and without mulching paper. There are a number of possible explanations of this phenomenon. The effect is so immediate after the fertilizer is applied, that it is doubtful if the effect is due to increased growth and greater shading of the soil of the fertilized plots. It is more probable that the effect is caused by a slight change in the degree of dispersion of the soil colloids and consequent increased retention of moisture.

The nitrate determinations are recorded graphically in Fig. 5. It is very clear that the adsorption of nitrates from the soil of the fertilized plots was not so rapid as in the experiments previously recorded in which nitrogen was applied during the months of more rapid growth. The increased nitrogen content of the soil in the N plot caused by the fall fertilization was sufficiently large so that there is no definite evidence of an increased nitrogen content in the soil of this plot after the February fertilization. The effect of this fertilization is, however, evident in an increased nitrogen content of the soil of the check plot. Neither plot showed any great evidence of an increased content of nitrate nitrogen after the April fertilization, though the nitrates in the soil of the former unfertilized plot are more evident than in the N plot. No further nitrogen applications were made,

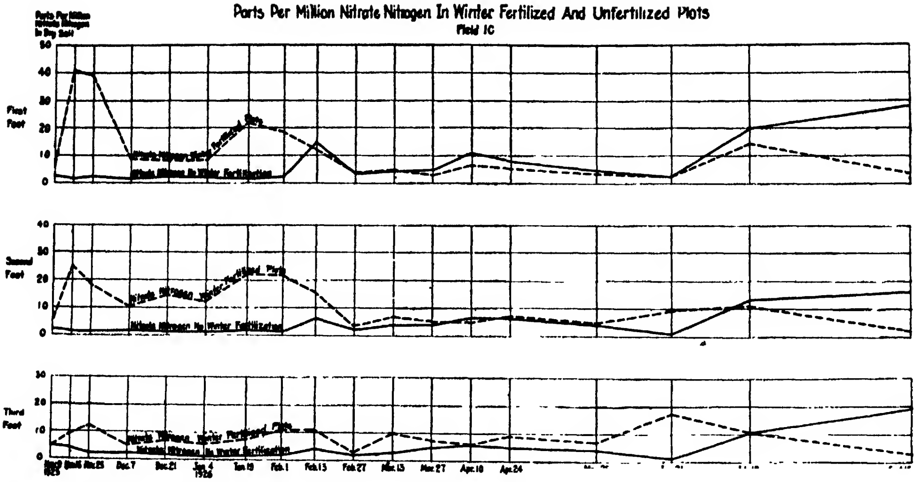


Fig. 5

but there was a noticeable increase in the content of nitrate nitrogen in July. This increase persisted into September. This would point to a rapid stimulation of nitrification of soil organic nitrogen as a result of higher soil temperatures.

The increase in growth caused by the winter fertilization is shown by graphic representation of the average total growth of the two plots in Fig. 6. These measurements were made by the agricultural department of Ewa Plantation. The winter of 1925-26, in which this winter application was made, was an unusually dry winter, so it was probably an exceptionally favorable season for winter growth of cane without heavy rains to remove soluble nitrates from the upper horizons of the soil. In our experiment there is considerable evidence of sufficient adsorption of nitrate nitrogen so that the major portion of the fall application was retained in the upper two feet of the soil column. Under these conditions this late fall fertilization might be considered to be successful so far as nitrate retention is concerned.

Effect of Nitrate of Soda Upon Soil Reaction

It is commonly believed that the continuous application of nitrate of soda will cause a gradual change in the soil reaction so that soils fertilized with this salt over a period of years will tend to become slightly alkaline. The soil samples collected in our soil survey work do not show that there is any great tendency towards the formation of alkaline residues as a result of the application of nitrate of soda. In our present experiments we determined the reaction of all or a portion of the individual soil samples at each sampling period. As this is a subject which has caused a good deal of discussion in the past, we give the average figures for each portion of the soil horizon, at each sampling period in the table. It will be seen that the reaction before and after fertilization is practically the same in every case except one, that is the fall fertilization in Field 22 C. Portions of this soil contain appreciable quantities of lime, and it is believed that the change noted in the pH of the soil is more likely to be due to differences in the lime content of the portions of the plots which were sampled.

SOIL REACTION BEFORE AND AFTER FERTILIZATION

Soil Reaction Field 6
Before and After Fertilization with 650 lbs. Nitrate of Soda
Results Expressed as pH

	Aug. 14 Before Fert.			Aug. 31	Sept. 5	Oct. 25	Nov. 23	Before Fert. Mar. 12	After Fert. Mar. 15	Apr. 9	May 28
First Foot	7.7	7.8	7.9	7.8	7.8	7.9	7.9	8.2	8.1	8.1	8.1
Second Foot	7.6	8.0	7.9	7.8	7.8	7.8	7.7	8.2	8.1	7.9	8.1
Third Foot	7.4	7.8	8.0	7.8	7.8	7.8	7.7	8.0	8.0	7.8	7.9
Fourth Foot	7.4	7.7	7.9	7.8	7.8	7.8	7.8	8.0	7.8	7.8	7.9

Soil Reaction Field 22 C
Before and After Fertilization with 650 lbs. Nitrate of Soda
Results Expressed as pH

	Aug. 14 Before Fert.			Aug. 31	Sept. 5	Oct. 25	Nov. 23	Before Fert. Mar. 12	After Fert. Mar. 15	Apr. 9	May 28
First Foot	7.8	8.3	8.0	8.0	8.1	8.0	8.0	8.5	8.5	8.2	8.3
Second Foot	8.0	8.4	8.0	8.0	8.1	8.1	8.1	8.5	8.1	8.1	8.1

Soil Reaction Field 26
Before and After Fertilization with 650 lbs. Nitrate of Soda
Results Expressed as pH

	Before Fert. Sept. 14	After Fert. Sept. 18	Sept. 25	Oct. 2	Oct. 30	Nov. 13	Before Fert. Mar. 19	After Fert. Mar. 26	Apr. 16	Apr. 30	June 4
First Foot	7.8	7.8	7.8	7.7	7.9	7.9	7.9	7.9	7.8	7.9	7.7
Second Foot	7.9	7.9	7.9	7.8	7.9	7.8	7.9	8.0	7.9	7.9	7.8
Third Foot	7.9	8.1	8.1	7.9	8.2	8.1	8.2	8.1	8.1	8.2	7.9
Fourth Foot	7.8	7.9	7.9	7.8	7.9	7.9	7.9	7.9	8.0	8.0	7.7

Soil Reaction Field 1 C
Soil Reaction of Winter Fertilized and Unfertilized Plots
Field 1 C X Plots No Winter Fertilization

	Nov. 9 1925	No. Fert. Nov. 16	Nov. 23	Dec. 7	Dec. 21	Jan. 4	Jan. 19	Feb. 1	After Fert. Apr 10	Apr. 24	June 21
First Foot	7.6	7.7	7.6	7.7	7.6	7.6	7.6	7.6	7.6	7.6	7.7
Second Foot	7.5	7.5	7.6	7.5	7.5	7.6	7.6	7.5	7.5	7.4	7.6
Third Foot	7.3	7.4	7.4	7.3	7.4	7.5	7.4	7.4	7.4	7.3	7.5

Field 1 C N Plots Winter Fertilized

	Before Fert. Nov. 9 1925	After Fert. Nov. 16	Nov. 23	Dec. 7	Dec. 21	Jan. 4	Jan. 19	Feb. 1	After Fert. Apr. 10	Apr. 24	June 21
First Foot	7.6	7.7	7.6	7.7	7.7	7.7	7.6	7.6	7.6	7.6	7.7
Second Foot	7.6	7.6	7.6	7.4	7.5	7.7	7.5	7.4	7.4	7.4	7.5
Third Foot	7.5	7.4	7.3	7.3	7.3	7.5	7.3	7.2	7.2	7.1	7.3

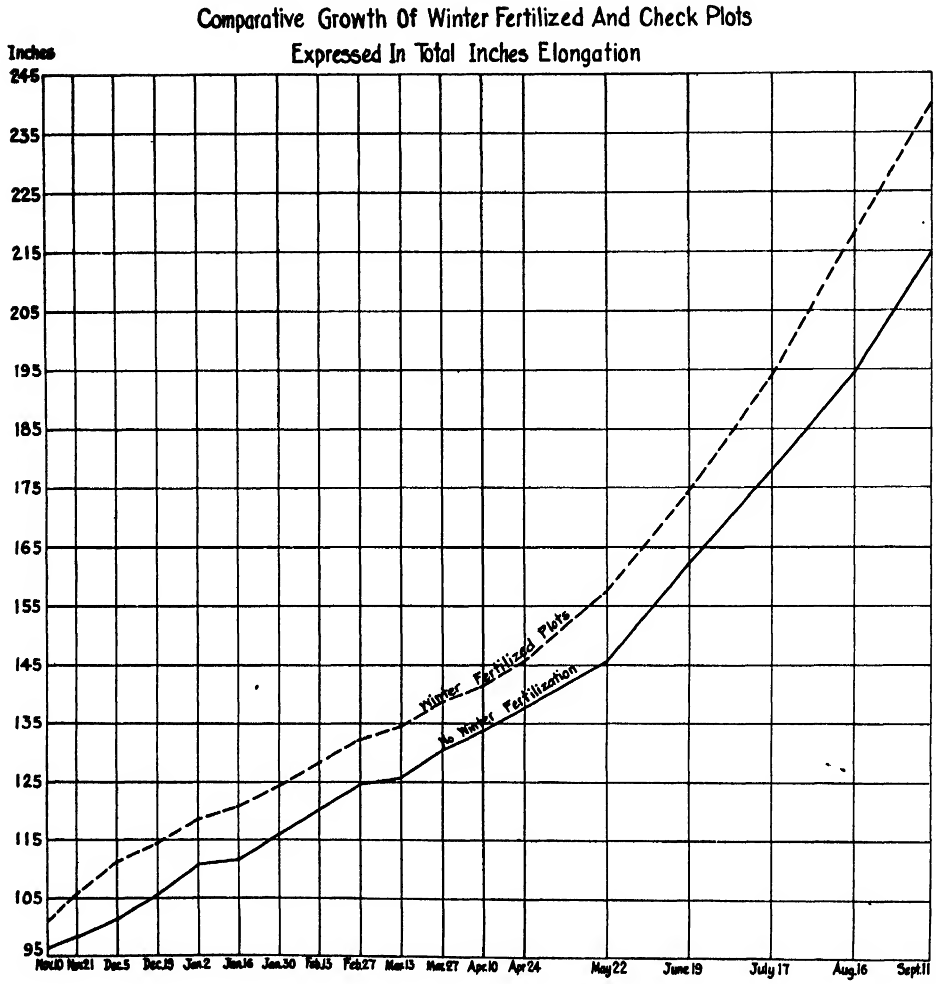


Fig. 6

SUMMARY

1. The experiments recorded here are an attempt to follow the content of soluble nitrogen compounds in several typical Island soils, before and after fertilization with nitrate of soda.

2. Determinations of ammonia and nitrite nitrogen in water solutions showed that there were never more than minute traces of soluble ammonia nitrogen, and constant small amounts of nitrites present in the soils, at the various sampling periods.

3. Determinations of the soluble nitrate nitrogen in all the soils showed an appreciable increase in nitrates in the surface soil after fertilization. There was a smaller increase in the nitrate content of the second foot of soil than was found in the top soil. Slight increases of nitrate nitrogen occurred in the third foot of soil, and still smaller increases were found in the nitrates present in the fourth foot of soil following nitrate fertilization.

4. It is believed that the determinations of nitrate nitrogen, before and after fertilization, indicate clearly that the greater portion of the added nitrates were retained in the upper two feet of the various soils.

5. The relative penetration of moisture and nitrates into the lower horizons of the soils would suggest that part of the retention of nitrates in the upper two feet of soil is due to adsorption by the colloidal complex of the soil.

6. Comparison of the moisture content of fertilized and unfertilized soil shows a small but definite increase in moisture content as a result of fertilization with nitrate of soda.

7. The disappearance of the added nitrates from the soils occurred in eight to twelve weeks when the nitrogen was added in the late summer or early spring season. In the case of the winter fertilization in Field 1 C, the added nitrates had not disappeared in 14 weeks, at which time the spring fertilization was applied. Since the added nitrates were never detected in large amount in the third and fourth foot of soil, we believe we are justified in concluding that the disappearance of nitrates was caused by the extraction of this nutrient through the growth of the cane crop.

8. No determinable change in soil reaction occurred as the result of one or two fertilizations with 650 pounds nitrate of soda per acre, applied to the soils used in our experiments.

Literature Cited

(1) Gedroiz, K. K. The Absorbing Capacity of the Soil and the Zeolitic Bases of the Soil. Zhur. Opit. Agron., Vol. 17, pp. 472-527.

(2) Hance, F. E., and Stewart, Guy R. 1927. Replaceable Bases in the Soils of Central Maui. Hawaiian Planters' Record, Vol. 31, pp. 342-354.

(3) Hissink, D. J. 1924. Base Exchange in Soils. A General Discussion Held by the Faraday Society, p. 553.

(4) Kelley, W. P., and Brown, S. Melvin. Replaceable Bases in Soils. Cal. Agr. Exp. Sta. Tech. paper No. 15, pp. 1-39.

(5) Lachs, H., and Michaelis, L. The Adsorption of Neutral Salts. Z. Chem. Ind. Kolloide 9, pp. 375-382.

(6) Maxwell, Walter. 1897. Report of the Work of the Experiment Station, H. S. P. A., page 16.

(7) Osaka, Yukichi. 1915. Adsorption of Strong Electrolytes. Mem. Coll. Sci., Kyoto Univ. 1, pp. 257-268.

(8) Peck, S. S. 1911. Lysimeter Experiments. Bull. 37, Agr. and Chem. Series, Expt. Sta., H. S. P. A., pp. 1-38.

(9) Stewart, Guy R. 1918. Effect of Season and Crop Growth in Modifying the Soil Extract. Jour. Agr. Research, Vol. 12, pp. 311-368.

(10) Stewart, Guy R. 1922. The Absorption and Interaction of Fertilizer Salts and Hawaiian Soils. Hawaiian Planters' Record, Vol. 26, pp. 186-195.

(11) Stewart, Guy R., Thomas, E. C., and Horner, J. 1926. Some Effects of Mulching Paper on Hawaiian Soils. Soil Science, Vol. 22, pp. 35-59.

Vitamin-like Substances in Plant Nutrition With Some Comments on Molasses Fertilization

By W. T. McGeorge

There has recently appeared from the Arizona Experiment Station a bulletin by J. F. Breazeale on "Vitamin-like Substances in Plant Nutrition." In view of the local interest being revived in fertilization with molasses, the views expressed in this bulletin on the effect of organic fertilizers are of more than passing interest.

It brings to mind the early work of Bottomley and previous work by Breazeale which demonstrated that in water cultures plant growth is often greatly improved if along with mineral nutrients a water extract of organic material, such as manure or peat, is added. In fact, their observations led to the assertion that soluble organic materials are at least helpful if not essential in plant growth. Bottomley used nucleic acid derivatives from bacterized peat, growth products of *Azotobacter chrococuum* and *B. radicicola,* leaf mould, fresh and rotted stable manure and well manured soil, and found that the water extract of all promoted growth in his plants. Breazeale used dilute extracts of peat and obtained a marked stimulation of root growth in citrus seedlings which could not be obtained with corresponding mineral nutrients.

Bottomley's experiments led him to suggest that plants required growth-promoting accessory factors similar to the vitamins — he called them auximones — needed in human nutrition. A commercial preparation along the above theory, known as "humogen" and prepared from bacterized peat, gave disappointing results at Rothamsted. Later Clark and Roller discovered what appeared to be experimental errors in Bottomley's culture studies, which led them to take issue with his conclusions and to question any basis for the analogy of vitamins.

Discussion of this phase of plant nutrition has been reopened by the recent bulletin by Breazeale. Some of the salient points which he brings out are as follows:

> The decomposed remains of most plants possess the peculiar property of stimulating the growth of other plants.
>
> While fermenting, nearly all forms of vegetable matter are toxic, including even stable manure.
>
> It is well known that no crop should be planted upon land immediately after an application of fresh manure or after plowing under a heavy growth of green vegetable matter. While it is true that much benefit is derived from inorganic fertilizers upon field crops, yet there is an "appearance" to a plant growing in a soil which has been manured that is different from that of a plant growing in a soil that has not been so treated.
>
> CROP ROTATION AND GREEN MANURING
>
> An adequate supply of stable manure seldom can be obtained on the farm, and it is not always economical to devote a full season's growth to a crop that can be used only for green manuring. For these reasons, in practically all systems of agriculture, and with nearly all cultivated crops, some form of rotation is necessary. With most plants rotation is the order of nature. Natural rotation may be very slow as with the great trees of the forest, or it may be very rapid as with many annuals. Even when the major forest growth appears to

be permanent there is often a rotation going on in the underbrush. When the virgin or hardwood forests of the South are cleared, they nearly always come up in pine timber. Few plants are so constituted that they will grow to advantage in a soil that has been continuously cropped with their own species. There are some exceptions, but it may be said safely that most agricultural crops are benefited by a rotation, and that for certain crops a rotation is almost a necessity.

The application of stable manure, the growing of "catch" crops intercropping with cover crops, green manuring and rotation, all accomplish the same beneficial results — all bring organic matter into the soil.

A soil is good only because it has the ability to produce a good crop. A soil may contain plant food in abundance and yet not be a good soil, or a soil may be in excellent physical condition and yet not produce a good crop. The maintenance of fertility, therefore, involves factors other than the supply of plant food or the mechanical condition of the soil.

A plant will often react to a change in soil conditions that cannot be detected by physical or chemical means.

Vitamins in Plant Nutrition

The term vitamin, as applied to plant nutrition, must not be misunderstood. By this term is meant certain organic compounds, not ordinarily considered as plant foods, that are required by plants, and that are effective in exceedingly small amounts.

During the past 25 years the writer has grown, handled and watched many hundreds of thousands of seedlings of different plants in an effort to find out something of their likes and dislikes and of their food requirements, and during this time many phenomena have been observed that cannot be explained by the usually accepted plant food theories. Much fragmentary evidence is at hand that teaches that plants require certain organic compounds, which may be called vitamins, and that are just as necessary in plant life as are other vitamins in animal life.

So much for his comments preceding his experimental data. For his culture experiments he evaporated to dryness a water extract of manure. The black powder which he obtained was extracted with diluted alcohol in order to remove all the inorganic plant foods, and then he redissolved the black residue in water. Using wheat seedlings he obtained a greatly enhanced growth with the solution of the organic material which had been freed from inorganic salts, and no improvement in growth from the alcohol-soluble inorganic material. He thus has shown that the active constituent of manure is the water-soluble organic matter. Further experiments were conducted with citrus with significant results and his comments are of interest. "Cactus and creosote bush having grown for ages on the desert would probably not profit by application of organic matter." But the attempts to grow citrus under the same conditions, which are not the environment of its adaptation, have often met with disaster. Applications of organic matter are now known to be vitally essential in citrus culture of the Southwest. To quote Breazeale further:

Many times has the writer planted healthy citrus seedlings, and given them restricted food ration, consisting of nitrogen, phosphorus and potash, but no organic matter. Symptoms of malnutrition are almost sure to appear. Usually the seedlings may be restored to healthy normal condition by the addition of organic matter, sometimes in exceedingly small amounts. A thimbleful of peat or leaf mould, or a small amount of bog water, when sprinkled upon the top of a pot containing unhealthy citrus seedlings, will often cause the seedlings to turn green and start out anew with a vigorous growth. Undernourished trees a year old have

been converted to normal trees in a short time by the application of small amounts of leaf mould.

In addition to the above he cites the work of McCarrison in India, which showed that millet grown on manured plots was more nutritious and of higher vitamin content than that grown on plots receiving only inorganic fertilizers.

Breazeale's conclusions are:

1. Certain plants, upon decomposing, develop compounds that stimulate the growth of other plants.
2. The stimulating property of manure rests largely in the black, water-soluble organic matter, and not in the plant foods, nitrogen, phosphate or potassium that it contains.
3. From observation on seedlings, it appears that many plants, in order to develop normally, require certain organic compounds in the soil that are usually considered as plant foods. These compounds are effective in exceedingly small amounts, and they are necessary in plant nutrition because they are one of the factors that have made the plant what it is today.
4. The beneficial effects of manuring and crop rotation are due in large part to the fact that vegetable matter develops or sets free certain organic compounds that are essential to the growth of plants.

The question arises, is there any analogy of the above line of reasoning to molasses fertilization? The fertilizer value of this material has been ably reviewed by Moir in the January *Record*. From this we learn that its use is general in Mauritius and to less extent in Java and certain of the West Indian countries.

We learn further that success has only followed its intelligent use; in other words, the adoption of methods which have been arrived at through careful study of conditions under which it has been applied, that is, amounts applied and whether applied to growing cane or while the land is in fallow, and, too, with due consideration to the physical texture of the soil. At first, attempts were made to estimate the value of molasses upon the basis of its plant food content. This falling short led to an inclusion of its effect upon nitrification, ammonification and nitrogen fixation. In reading over the literature on this subject there still appears an air of mystery underlying the enhanced growth obtained on some soils as the following quotations from literature will show:

Considerations drawn from these experiments show that the increases are too large to be attributed entirely to plant food conveyed by the molasses to the soil; consequently, some other contributing cause must be sought. This is probably biological in nature.

Stimulation to nitrogen fixation has been suggested, but experiments do not substantiate this for good soils.

Nitrification is entirely suspended following the addition of molasses, to be resumed later at an enhanced rate.

A repopulation of soil takes place.

The results obtained are superior to those that would be produced by the same quantity of nitrogen and potash in artificial manures. The influence of the molasses would not appear to be exhausted during the first year and seems to make itself *felt for some time.*

In reviewing the literature on fertilizaztion with molasses one significant feature is, to the writer, that the role of yeast has attracted no attention. In the high carbohydrate content of the molasses, we are adding to the soil, compounds which depend largely upon yeast for their chemical destruction. Yeasts are plants, just as much so as sugar cane, requiring nitrogen, potash and phosphate. The

vigorous development and rapid increase in yeast population of the soil would, therefore, take available plant food away from the cane roots and there would necessarily follow an *apparent* injury to cane growth. One of the principal requirements of cane root respiration is a supply of oxygen. Carbon dioxide is the excretory gas of root respiration. The same process applies to yeast plants, and here again may we not have the more actively growing yeast assimilating the major part of the oxygen in the soil atmosphere and poisoning the cane roots with its own respiratory products? In other words, in adding molasses to growing cane there is produced a highly competitive situation in which the cane plant is greatly outclassed in competition with such an actively growing plant as yeast in a carbohydrate medium. This is shown in the injury to growing cane following heavy molasses applications and lack of injury or enhanced growth from light applications. In other words, an overpopulation of yeast plants in the former and a minimum or optimum population in the latter.

All seem agreed that molasses accelerates denitrification and nitrogen fixation but retards ammonification and nitrification. Is this strictly true or only apparent? Rather, may it not be simply a question of terminolgy? Articles published, covering the several phases of molasses fertilization, fail utterly to establish proof of either denitrification or retarded ammonification or nitrification in the usual sense of these terms. True, their observations have shown a disappearance of soluble nitrogen salts. In place of the so-called denitrification and nitrogen fixation by bacteria, may not the above observations (disappearance of ammonia and nitrate nitrogen) be caused by the yeast plant grasping all the available nitrogen in building its own protoplasmic bodies in the form of protein compounds? In the large bread bakeries nitrogen salts are often added to the yeast as food.

Peck found "that after the disappearance of the sugars in the molasses in Series D, the soil was able to regain some of its original powers of ammonification and nitrification; with fresh molasses being applied at two-week intervals, these powers were kept continually in check."

In other words, the yeast plants exhaust, in so far as needed, the storehouse of nitrogen and possibly other forms of plant food in satisfying the needs of their own metabolic processes. The period of activity of the yeast is limited by the amount of carbohydrate supplied in the molasses. When this is exhausted the accumulated nitrogen (or other plant foods) becomes available for the cane, as it is now present in an easily nitrifiable (or available) form.

On these bases are Peck's conclusions, as expressed in Experiment Station, H. S. P. A., Agricultural Bulletins 34 and 39, such a great point for controversy:

1. "Molasses applied at intervals on land on which cane is growing and fertilizer has been applied will work harm by destroying nitrates already supplied in the fertilizer." The writer would accept the above observations as well proven by Peck's investigations, but that the apparent "destroying of nitrates" is a result of the active assimilation of nitrates by the yeast plants. And "preventing of formation of nitrates" of being a result of rapid assimilation of nitrates as formed by nitrification or even as ammonium salts and, therefore, there is no chance for accumulation.

2. "Molasses applied to land lying fallow or at an interval of several weeks to the time of planting of the crop may produce beneficial results by providing a stimulus to the nitrogen fixing bacterial of the soil in a form which can be made readily available to the crop at a later date by the organisms in the soil." This observation is unquestionable in fact, but in theory is more easily explained if we consider yeast rather than bacteria as the principal accessory plant. The store of nitrogen is within the yeast plants in the form of easily available proteins. In applying the molasses during fallow, carbohydrate fermentation is at an end before planting and instead of competition we have the destructive processes supplying plant foods from the dead yeast plants.

Enzymes are among the most active agents in plant metabolism and katabolism. We know little of their composition, but much of their properties. They are believed to be of complex organic nature. Breazeale's interpretation of plant vitamins — auximones — as essential organic compounds would include enzymes. They are abundantly formed in the growth of the yeast plant.

The vitamin B of animal nutrition is pre-eminently present in yeast. The fact also that it is present in green leaves, growing parts of plants, and in the germs of grains and seeds may or may not be a significant analogy. The so-called vitamins of human nutrition are also complex organic compounds of little known composition.

Many other organic compounds are of possible formation in molasses fermentation. The Java Experiment Station reports that "the organic matter of molasses cannot be placed on a par with that resulting from the decay of vegetable matter. It is almost exclusively in the form of sugars which ferment and disappear very quickly in the soil without leaving anything behind which can be compared with humus." The writer would seriously question any grounds for such a broad conclusion. The final products of organic decomposition in soils depend so greatly upon side reactions — as in molasses the nitrogen compounds in the millions of yeast, bacteria and fungi formed during fermentation — that a vast number of organic compounds are possible of formation.

It is not overspeculative to suggest that the extended beneficial effects of molasses residual of the active fermentation period may be due in part to growth-promoting organic compounds such as found by Breazeale.

Identification of Sugar Cane Rust Mite or Stalk Mite

By C. E. Pemberton

A paper by Stanley Hirst, of the British Museum of Natural History, in *Bulletin of Entomological Research,* Vol. III, pp. 325-328, London, 1912, gives an account of a mite injurious to sugar cane in Barbados, with a careful description accompanied by good figures. Hirst considered this a new species and described it as *Tarsonemus spinipes* sp. n.

Minute comparisons of our common stalk mite with these figures, in December, 1927, indicated no difference between the species in Hawaii and that in Barbados. Our species has formerly been assumed to be *Tarsonemus bancrofti* Michael, a mite described from Queensland and listed from Java, Mauritius and Barbados. Specimens of our mite were sent to the British Museum in December for comparison with Hirst's type material of *Tarsonemus spinipes* from Barbados. Under date of February 1, 1928, we have received a communication from Susan Finnegan, of the British Museum, stating that our specimens agree with Hirst's type of *Tarsonemus spinipes.* Our mite then, must henceforth be *Tarsonemus spinipes* Hirst, and not *T. bancrofti* Michael.

We have formerly assumed that our species was different from *T. spinipes,* because the latter has been described in Porto Rico by Smyth (*The Journal of the Department of Agriculture of Porto Rico,* Vol. III, Part IV, p. 92, 1919) as especially attacking Yellow Caledonia cane. As it does not become numerous on Yellow Caledonia in Hawaii, it has been believed that our species might be different. Recent examinations, however, of Yellow Caledonia in Honolulu, showed the mite nearly always present on the cane, but never in injurious numbers. It is possible that climatic or growth conditions for Yellow Caledonia in Porto Rico may in some unknown way favor the mite there. The mite is highly sensitive to slight differences in the texture of different cane varieties. Some examinations of cane varieties in Honolulu during January showed wide differences in susceptibility to *tarsonemus* attack and are summarized below:

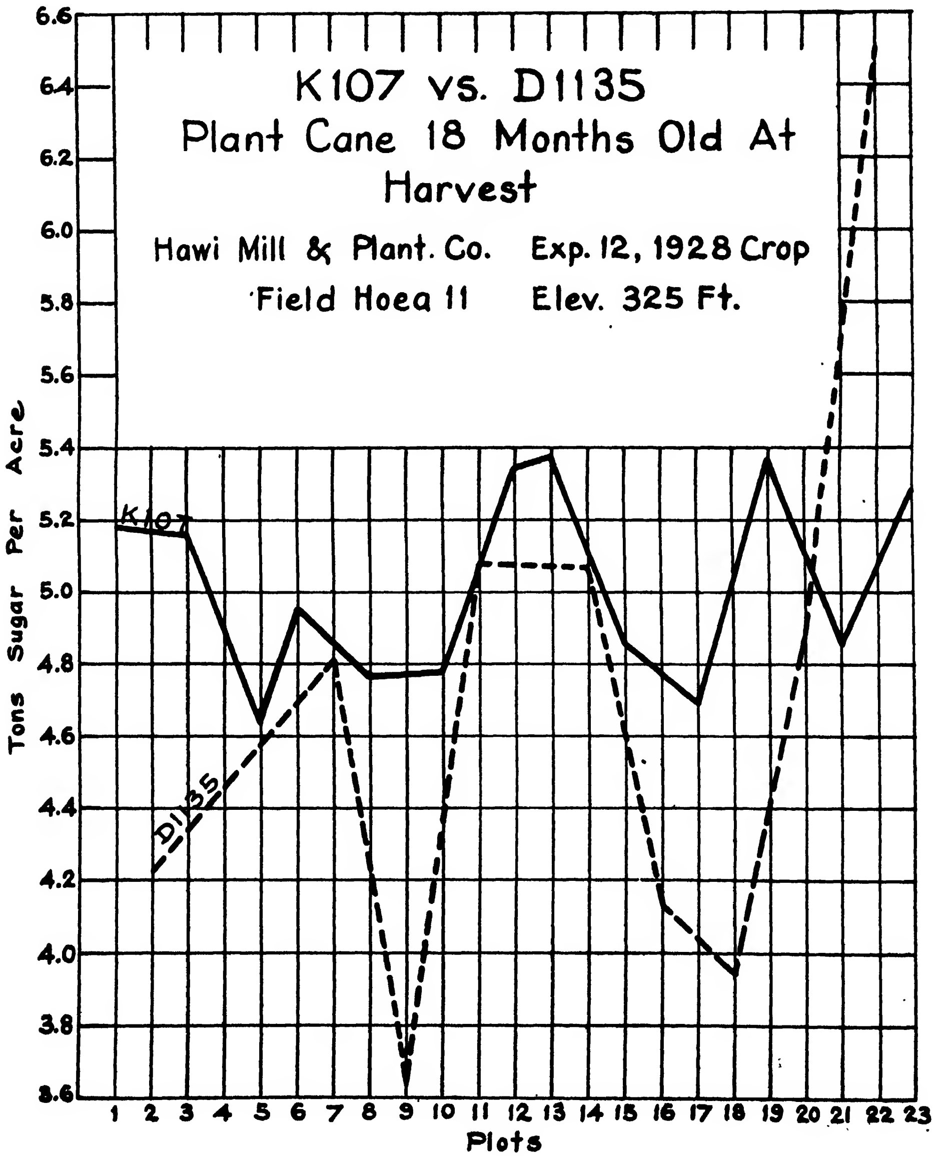
U. D. 1	*Tarsonemus*	rare
Uba	"	"
U. D. 110	"	"
Badila	"	uncommon
Lahaina	"	"
P. O. J. 979	"	"
P. O. J. 234	"	"
Kassoer	"	"
Yellow Caledonia	"	"
P. O. J. 36	"	fairly common
H 8965	"	"
U. D. 13	"	"
Yellow Tip	"	common
H 109	"	"
D 1135	"	"
Striped Mexican	"	"
27 C 429	"	very common

Kohala 107 Shows Up Well in Large Test

HAWI MILL & PLANTATION COMPANY, EXPERIMENT 12

By J. A. Verret

The cane in this test was planted July 16, 1926, and harvested in January, 1928. The field was an irrigated one at an elevation of 325 feet. The layout consisted of twenty-three plots with a total area of 3.2 acres. Each plot was two water-



courses in size. All plots received uniform fertilization in accordance with the plantation practice.

K 107 shows consistent gains over adjoining D 1135 plots. This is true in all cases except one. (See graph.) D 1135, plot 22, gave the abnormally high yield of 63 tons per acre. This is much higher than the yield of any other plot. We believe this to be an error or due to much better soil conditions than those met with in the rest of the experimental area. But we did not omit this plot from the calculations, and the gain of K 107 over D 1135 was in spite of this exceptionally high yielding plot of D 1135.

The behavior of K 107 in rather extensive field plantings shows this cane to be resistant to eye spot, mosaic and red stripe. It ratoons well and closes in somewhat faster than D 1135. As a rule it is not a free tasseler.

Reports to date indicate that by next year, K 107 will be planted to over 1,000 acres.

The summary of the harvest and the detailed yield by plots are given as follows:

HAWI MILL AND PLANTATION COMPANY

Experiment No. 12, 1928 Crop, January 30, 1928.

Object:	Variety test, comparing K 107 with D 1135.
Layout:	Plots consist of two watercourses each, areas are irregular, total area 3.2159 acres.
Location:	Field Hoea 11, elevation 325 feet.
Cane:	K 107 and D 1135.
Fertilization:	Uniform by plantation.

Harvesting Results — Summary

Variety	No. Plots	Average Tons Cane Per Acre	Q. R.	Average Tons Sugar Per Acre
K 107	13	47.6	9.5	5.02
D 1135	9	45.	9.8	4.6
In favor of K 107		2.6	.3	.42

Experiment carried out by A. J. Watt, Jr.
Experiment harvested by A. H. Cornelison.

HARVESTING RESULTS IN DETAIL

Plot No.	Variety	Area	Tons Cane Per Plot	T. C. P. A.	Q. R.	T. S. P. A.
1	K 107	.1917	9.441	49.248	9.5	5.184
3	K 107	.1677	8.230	49.075	9.5	5.166
5	K 107	.1095	4.829	44.100	9.5	4.642
6	K 107	.1164	5.474	47.027	9.5	4.950
8	K 107	.1301	5.882	45.211	9.5	4.759
10	K 107	.1061	4.809	45.325	9.5	4.771
12	K 107	.1130	5.728	50.690	9.5	5.336
13	K 107	.0856	4.364	50.987	9.5	5.367
15	K 107	.0993	4.576	46.082	9.5	4.851
17	K 107	.1472	6.555	44.531	9.5	4.687
19	K 107	.1267	6.453	50.931	9.5	5.361
21	K 107	.1198	5.515	46.035	9.5	4.846
23	K 107	.1575	7.896	50.133	9.5	5.277
Averages				47.644	9.5	5.075

2	D 1135	.1780	7.370	41.404	9.8	4.224
4	D 1135	.1437	Cast out due to error by labor.			
7	D 1135	.1232	5.809	47.151	9.8	4.811
9	D 1135	.1369	4.874	35.602	9.8	3.633
11	D 1135	.1198	5.963	49.774	9.8	5.078
14	D 1135	.0856	4.252	49.673	9.8	5.068
16	D 1135	.1164	4.709	40.455	9.8	4.128
18	D 1135	.1506	5.834	38.738	9.8	3.953
20	D 1135	.1301	6.212	47.747	9.8	4.872
22	D 1135	.1267	8.076	63.741	9.8	6.504
Averages				45.032	9.8	4.595

In arriving at the tons of cane per plot, every bundle was weighed.

Juice analysis was carried out by Mr. Richmond, plantation chemist, with results as tabulated below:

Car	Variety	Brix	Temp.	Pol.	C. Brix	C. Pol.	Pur.	Q. R.	C. R.
87	K 107	18.7	23	64.1	18.38	15.53	84.4	8.9	9.03
23	K 107	17.6	23	57.9	17.28	14.09	81.5	10.1	10.19
55	D 1135	17.6	25	59.9	17.42	14.37	82.5	9.8	9.92

Iron Sulphate Spray for Coral Chlorosis

EWA PLANTATION COMPANY, EXPERIMENT 1, 1928 CROP

By J. A. Verret

This experiment was conducted by the Ewa Plantation Company and the Experiment Station, H. S. P. A.

The test was in Field 9A, in one of the so-called coral areas. The cane was H 109, first ratoons, and was 21.5 months old when harvested on January 6, 1928. The layout consisted of eleven watercourse plots of irregular size.

The cane received but one spraying, on June 18, 1926, when 3 months of age. The spray was applied in the form of a 5 per cent solution at the rate of 18 pounds of iron sulphate per acre. The labor for this spraying was at the rate of 0.493 man-day per acre and the iron sulphate cost 30 cents per acre.

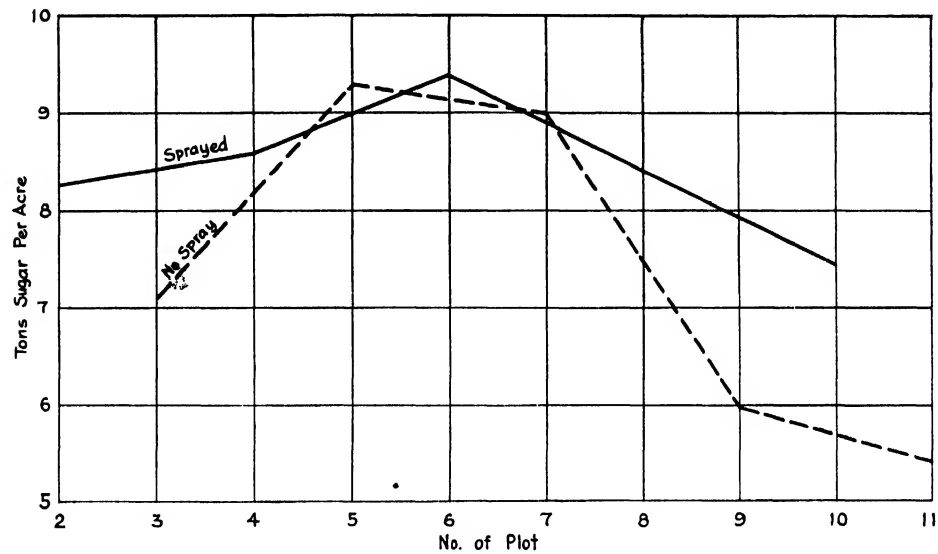
Growth measurements were started on June 29, 1926, and carried on at two-week intervals until September 21, 1926. The measurements were taken on ten stalks per plot. Growth measurements in a test of this kind are not satisfactory in that it is not possible to get average stalks. Many of the diseased stalks do not grow at all, and finally die. The figures are given for what they are worth:

	June 29 to July 13	July 13 to July 27	July 27 to Aug. 10	Aug. 10 to Aug. 24	Aug. 24 to Sept. 9	Sept. 9 to Sept. 22	Total growth during period
Sprayed	0.30′	0.38′	0.43′	0.75′	0.43′	0.68′	2.97′
Unsprayed	0.19′	0.27′	0.34′	0.65′	0.47′	0.69′	2.61′

We note that from June 29 to August 24 the sprayed plots made considerably more growth than the unsprayed plots. From September on, the rate of growth was the same throughout the area. This is explained by the fact that by this time the majority of the chlorotic stalks in the unsprayed plots had either recovered or died.

IRON SULPHATE SPRAY FOR LIME CHLOROSIS

Ewa Plantation Exp. I, 1928 Crop



On March 3, 1927, a stalk count was made. Only full lines were taken, and the outside lines were not counted.

The results of this count are interesting:—

Plot	9 — No spray	= 61	stalks per line
"	10 — Spray	= 77	" " "
"	3 — No spray	= 79	" " "
"	2 — Spray	= 90	" " "
"	5 — No spray	= 82	" " "
"	4 — Spray	= 87	" " "
Average No spray plots		= 74	" " "
Average Spray "		= 85	" " "
Difference		= 11	" " "

This shows a difference of 13 per cent less stalks in the unsprayed plots. This difference in favor of the sprayed plots was noted in all the plots counted. We feel that in an experiment of this kind, a stalk count is a more accurate indication of actual conditions than are growth measurements.

Ewa Plantation Company computed the results of the harvest and commented as follows:

SUMMARY OF HARVESTING RESULTS — YIELD PER ACRE

Treatment	Cane	Q. R.	Sugar
	(General — True Average)		
Iron sulphate spray	83.52	9.95	8.39
No spray (Base)	72.75	9.91	7.34
Gain or loss for sprayed plots	+10.77	—0.04	+ 1.05
% Gain or loss for sprayed plots	+14.80%	—0.40%	+14.31%
	(Arith. Average — Adjacent Plots)		
Iron sulphate spray	84.12	9.99	8.42
No spray (Base)	73.11	9.97	7.33
Gain or loss for sprayed plots	+11.01	—0.02	+ 1.09
% Gain or loss for sprayed plots	+15.06%	—0.20%	+14.87%

PLOT-TO-PLOT COMPARISON

	Total	For Sprayed	Same	For Not Sprayed	Odds
Cane	7	5	0	2	19.5 : 1
Quality Ratio	7	4	0	3	9.42 : 1
Sugar	7	5	1	1	......

NITROGEN — RATE OF APPLICATION (SAME AS FIELD APPLICATION)

Age	4.7 Mos.	5.8 Mos.	11.4 Mos.	13.2 Mos.	
Date Applied	Aug. 12/26	Sept. 15/26	Mar. 4/27	Apr. 28/27	Total
Nitrogen (Lbs.)	51	81	78	100	310

IRON SULPHATE SPRAY VS. NO SPRAY

Cane: In this co-operative test with the Experiment Station, average cane yields show a gain of almost 11 tons per acre for the plots which received the iron sulphate spray treatment when the cane was 3 months old. Five out of 7 plot-to-plot comparisons confirmed the average results, although, according to Student's methods, the data were not significant.

Q. R.: Identical average quality ratio results were secured. Plot-to-plot comparisons about broke even.

Sugar: The average gain in sugar yields for the treated plots was 1 ton per acre. This 14 per cent gain was substantiated in 5 out of 7 plot-to-plot comparisons.

Summary: This is the first experiment to be harvested in which chlorotic cane was treated with a 5 per cent solution of iron sulphate when the cane was 3 months old, applied at the rate of about 18 pounds per acre. If the results of this experiment can be duplicated in practice, it appears that iron sulphate can be sprayed on cane having coral soil type of chlorosis. with considerable profit. As these are the first results along this line, the experiment should be repeated.

Evaluation of Yield Equations

By Y. Kutsunai and E. L. Caum

In the article "The Yield Equation and Its Application to Sugar Cane Agriculture," appearing in the *Record* for January, 1928, the method of evaluating yield equations was omitted for the sake of simplicity. In this supplement a few numerical examples are worked to bring out the details of the process of computation.

Spillman's yield equation is: $Y = M - AR^x$, in which

Y = yield of cane in tons per acre.
M = the theoretical maximum cane yield due to natural soil fertility plus an unlimited amount of fertilizer.
A = the theoretical maximum cane yield due to an unlimited amount of fertilizer only, the natural soil fertility not being considered.
R = the ratio between successive increments in cane tonnage due to the progressive increase in amount of fertilizer.
X = number of lots of fertilizer applied;

or, to extend: the yield of cane is equivalent to the ratio between successive increments in tonnage due to fertilizer raised to the power of the number of lots of fertilizer, multiplied by the maximum yield of cane due to fertilizer alone, and subtracted from the theoretical maximum yield possible.

Formula (2a)* is $\log (Y_{X+1} - Y_X) = \log Z = X \log R + \log A\ (1-R)$.

The harvesting data of Lihue Plantation Company, Experiment 5, 1924 crop, are:

Pounds Nitrogen per acre	Nitrogen in lots of 75 lbs.	Actual tons cane per acre	Increments tons cane
0	0	27.31	12.46
75	1	39.77	8.11
150	2	47.88	5.01
225	3	52.89	....

The fertilizer is increased by one lot of 75 pounds of nitrogen per acre for each successive step and the increments in cane weight are all positive. The formula (2a) is applicable in this case.

$$\begin{array}{lll}
\log 12.46 = 1.0955180 & = 0 \log R + \log A\ (1-R) \\
\log\ \ 8.11 = 0.9090209 & = 1 \log R + \log A\ (1-R) \\
\log\ \ 5.01 = 0.6998377 & = 2 \log R + \log A\ (1-R) \\
\text{Total.........}\ 2.7043766 & = 3 \log R + 3 \log A\ (1-R)
\end{array}$$

This is the normal equation for $\log A\ (1-R)$

$$\begin{array}{lll}
1.0955180 \times 0 = 0 & = 0^2 \log R + 0 \log A\ (1-R) \\
0.9090209 \times 1 = 0.9090209 & = 1^2 \log R + 1 \log A\ (1-R) \\
0.6998377 \times 2 = 1.3996754 & = 2^2 \log R + 2 \log A\ (1-R) \\
\text{Total......................}\ 2.3086963 & = 5 \log R + 3 \log A\ (1-R)
\end{array}$$

* The use of these formulae is explained in the *Record* for January, 1928, p. 77.

This is the normal equation for $X \log R$. The two normal equations are solved for $\log R$ and $\log A\ (1-R)$ by elimination.

$$\begin{array}{rl} & 2.7043766 = 3 \log R + 3 \log A\ (1-R) \\ \text{By subtracting} & \underline{2.3086963 = 5 \log R + 3 \log A\ (1-R)} \\ & 0.3956803 = -2 \log R \end{array}$$

$$\log R = -0.1978402$$

By adding 1 and subtracting 1

$$\begin{aligned} \log R &= 1. - 0.1978402 - 1 \\ \log R &= 0.8021598 - 1 \\ R &= 0.6341 \end{aligned}$$

Substituting the value of $\log R$, which is -0.1978402, in one of the normal equations:

$$\begin{aligned} 2.7043766 &= 3 \times (-0.1978402) + 3 \log A\ (1-R) \\ &= -0.5935206 + 3 \log A\ (1-R) \\ 3.2978972 &= 3 \log A\ (1-R) \\ \log A\ (1-R) &= 1.0992991 \\ A\ (1-R) &= 12.569 \\ \text{But } 1 - R &= 1 - 0.6341 \\ &= 0.3659 \\ A &= \frac{12.569}{0.3659} \\ &= 34.351 \end{aligned}$$

Formula (2b) is $M = \dfrac{1}{n} (\Sigma\, Y + \Sigma\, AR^X)$

X	Y	AR^X
0	27.31	$34.351\ (0.6341)^0 = 34.351$
1	39.77	$34.351\ (0.6341)^1 = 21.782$
2	47.88	$34.351\ (0.6341)^2 = 13.838$
3	52.89	$34.351\ (0.6341)^3 = 8.758$
	$\Sigma\, Y = 167.85$	$\Sigma\, AR^X = 78.729$

$$\begin{aligned} M &= \frac{1}{4} (167.85 + 78.729) \\ &= 61.645 \end{aligned}$$

The yield equation sought is $Y = 61.645 - 34.351\ (0.6341)^x$, in which Y is the cane yield in tons per acre and X is the number of lots of fertilizer of 75 pounds of nitrogen per acre each.

The above method is not applicable when the fertilizer is not increased in steps of one lot each or when the increments in cane tonnage are not always positive. Formulae (3a) and (3b) are used in irregular cases of this nature.

Formula (3a) is $A_1 = \dfrac{\Sigma(Y)\Sigma(R^X) - N\Sigma(YR^X)}{N\Sigma(R^{2X}) - (\Sigma R^X)^2}$

and (3b) is $A_2 = \dfrac{N\Sigma(YXR^X) - \Sigma(Y)\Sigma(XR^X)}{\Sigma(R^X)\Sigma(XR^X) - N\Sigma(XR^{2X})}$

The data from Maui Agricultural Company, Experiment 5, 1922 crop, variety H 109, are:

Pounds nitrogen per acre	Difference in nitrogen	Actual tons cane per acre	Increments tons per acre
0	75	33.2	+ 10.8
75	50	44.0	+ 4.8
125	50	48.8	+ 4.4
175	50	53.2	— 0.9
225	....	52.3	....

In this experiment nitrogen was increased at first by 75 pounds and thereafter by 50 pounds. This irregularity in the fertilizer application necessitates the use of formulae (3a) and (3b). Not all the increments in cane weights are positive and this fact also calls for the formulae (3a) and (3b). Taking one lot of fertilizer as 25 pounds of nitrogen, which is the greatest common factor of the differences in nitrogen application, the data are rearranged as follows:

Number of lots of nitrogen	Actual tons cane per acre	Increments tons per acre
0	33.2	+ 10.8
3	44.0	+ 4.8
5	48.8	+ 4.4
7	53.2	— 0.9
9	52.3	....

A_1 and A_2 are computed with the assumed value of R. A and R are the correct ones to choose when A_1 and A_2 become equal or very nearly so for a certain assumed value of R. When such a value of R is not readily found, A_1 and A_2 are plotted as in the illustration, and at the intersection of the A_1 and A_2 lines, the values of A and R are read off the chart.

The computation is systematized as in the following table to avoid errors.

Assumed R = 0.78

X	Y	R^x	YR^x	XR^x	YXR^x	R^{2x}	XR^{2x}
0	33.2	1.000000	33.200000	0.000000	0.000000	1.000000	0.000000
3	44.0	.474552	20.880288	1.423656	62.640864	.225200	.675599
5	48.8	.288717	14.089390	1.443587	70.447046	.083358	.416789
7	53.2	.175656	9.344899	1.229590	65.414188	.030855	.215984
9	52.3	.106869	5.589487	.961820	50.303186	.011421	.102789
Σ	231.5	2.045794	83.104064	5.058653	248.805284	1.350834	1.411161

n = 5

$$A_1 = \frac{\Sigma Y \Sigma R^x - n\Sigma(YR^x)}{n\Sigma(R^{2x}) - (\Sigma R^x)^2} = \frac{231.5 \times 2.045794 - 5 \times 83.104064}{5 \times 1.350834 - (2.045794)^2}$$

$$= \frac{473.601311 - 415.52032}{6.754170 - 4.18527}$$

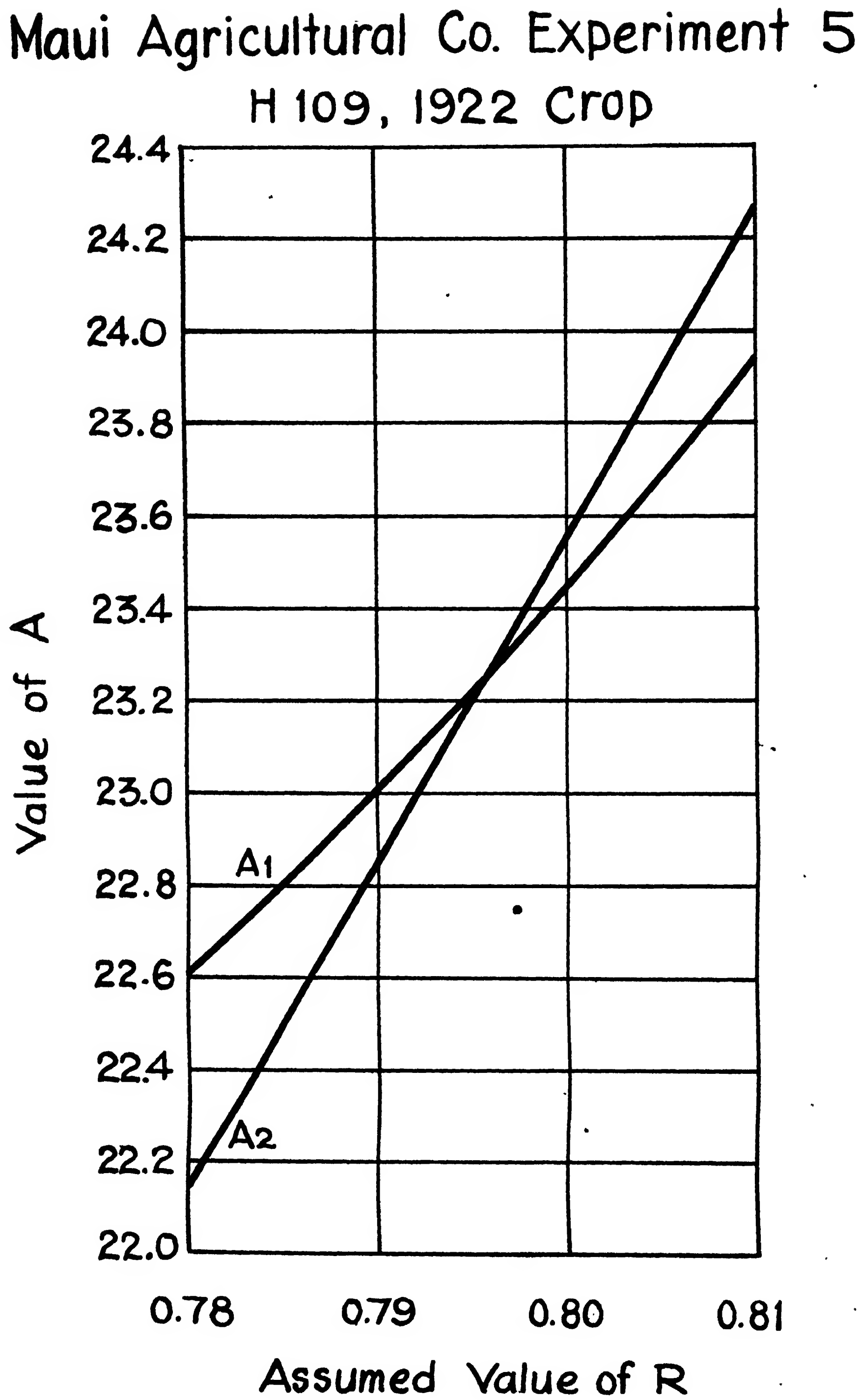
$$= \frac{58.080991}{2.568897} = 22.609$$

$$A_2 = \frac{n\Sigma(YXR^x) - \Sigma Y \Sigma(XR^x)}{\Sigma R^x \Sigma(XR^x) - n\Sigma(XR^{2x})} = \frac{5 \times 248.805284 - 231.5 \times 5.058653}{2.045794 \times 5.058653 - 5 \times 1.411161}$$

$$= \frac{1244.02642 - 1171.078170}{10.348962 - 7.055805}$$

$$= \frac{72.948250}{3.293157} = 22.151$$

Difference, $A_1 - A_2 = 0.458$


Maui Agricultural Co. Experiment 5
H 109, 1922 Crop
Value of A
24.4
24.2
24.0
23.8
23.6
23.4
23.2
23.0
22.8
22.6
22.4
22.2
22.0
A1
A2
0.78
0.79
0.80
0.81
Assumed Value of R

A_1 and A_2 worked out with the various arbitrary values of R are:

Assumed R	A_1	A_2	A_1-A_2
0.78	22.609	22.151	+ 0.458
0.79	23.008	22.846	+ 0.162
0.80	23.450	23.553	— 0.104
0.81	23.941	24.277	— 0.336

Between $R = 0.79$ and 0.80, the difference A_1 and A_2 passes the zero point. By plotting these values, it is seen that when $R = 0.796$, both A_1 and A_2 are equal to 23.25, hence the values sought are:

$$R = 0.796$$
$$A = 23.25$$

M is found by formula (2b)

X	Y	AR^x
0	33.2	$23.25\ (0.796)^0 = 23.25$
3	44.0	$23.25\ (0.796)^3 = 11.73$
5	48.8	$23.25\ (0.796)^5 = 7.43$
7	53.2	$23.25\ (0.796)^7 = 4.71$
9	52.3	$23.25\ (0.796)^9 = 2.98$
	$\Sigma\ Y = 231.5$	$\Sigma\ AR^x = 50.10$

$$M = \frac{1}{5}\ (231.5 + 50.10)$$
$$= 56.32$$

The yield equation sought is $Y = 56.32 - 23.25\ (0.796)^x$ in which Y is the cane tonnage per acre and X is the number of lots of 25 pounds of nitrogen each per acre.

The tables of values, to six decimal places, of R^x, XR^x, R^{2x}, and XR^{2x}, for R from .01 to .99 and X from 0 to 20, are ready for distribution. The tables will be sent on request to the Experiment Station, H. S. P. A.

Formula (5), which is $Y = M - \frac{A}{R^d}\ (R)^x$ is used in the cases where shifting of the zero point is necessary, as, for instance, when the first amount considered is not at the natural zero point, as in the case below.

The harvesting results of Pioneer Mill Company, Experiment 16, 1927 crop, are:

Pounds nitrogen per acre	Tons cane per acre
140	61.4
190	65.2
240	68.7
290	70.4

The common difference in fertilizer is 50 pounds per acre of nitrogen, which is taken as one lot, and if the initial amount of 140 pounds nitrogen is assumed to be the zero point, or no fertilizer, then the data become

Number of lots of nitrogen	Tons cane per acre	Increment tons per acre
0	61.4	+ 3.8
1	65.2	+ 3.5
2	68.7	+ 1.7
3	70.4	....

The yield equation obtained from these rearranged data by the formulae (2a) and (2b) is

$$Y = 74.134 - 12.767\ (0.66886)^{X}$$

The origin of this equation, however, must be shifted back to the natural no-fertilizer point. This is done by the use of formula (5) in which the distance $d = \frac{140}{50}$

Hence the true equation sought is

$$\begin{aligned} Y &= 74.134 - \frac{12.767}{0.66886^{\frac{140}{50}}}\ (0.66886)^{X} \\ &= 74.134 - 39.369\ (0.66886)^{X} \end{aligned}$$

in which Y is cane tonnage per acre and X is the number of lots of 50 pounds per acre of nitrogen.

It is almost needless to add that the harvesting data which are to be subjected to mathematical analysis must be fairly free from error; and that if the form of the curve traced by the harvesting data does not fit the yield equation of Spillman, then some other empirical formula must be chosen. Fundamentally, any mathematical formula that faithfully traces the relation between the yield and the growth factor, such as fertilizer or water, is applicable.

The Use of Yield Equations in Deciding the Proper Proportion of Plant Food to Apply

By Y. Kutsunai

It is often very difficult to work out satisfactorily the proper proportion of the major plant foods—nitrogen, phosphoric acid, and potash—to apply to the cane crop. Soil analyses, cane juice analyses, and the results of plant food tests have been used extensively as guides in arriving at the decision.

Additional assistance is found in the yield equations evaluated from the results obtained by applying varying amounts of plant foods. The number of equations needed corresponds to the number of the plant foods to be proportioned. For instance, if nitrogen, phosphoric acid, and potash are to be decided upon, then the yield equations on these three elements are needed. The three equations are plotted and the amount of each element needed to produce a given tonnage of cane is read off; or if greater accuracy is desired, computation may be resorted to.

A numerical example is worked out to clarify the above brief statement. In Field 45, Oahu Sugar Company, experiments were run with varying amounts of

nitrogen, phosphoric acid, and potash. Unfortunately, a different variety was used in each experiment, but for the purpose of illustration, the variety difference is ignored. The data follow:

Experiment 3, 1922 Crop, nitrogen test:

Pounds per acre N	Pounds per acre P_2O_5	Pounds per acre K_2O	Cane obtained Tons per acre
0	150	50	27.3
75	"	"	36.2
150	"	"	42.7
225	"	"	46.9
300	"	"	44.6
375	"	"	46.3

The yield equation obtained from the data is $Y = 46.99 - 20\ (0.48)^x$ in which X is in lots of 75 pounds of nitrogen. The amount of nitrogen necessary to produce a given tonnage of cane under the condition of the test is:

Tons cane per acre	Pounds N per acre
30	17
35	52
40	107
45	235

Experiment 4, 1922 Crop, phosphoric acid test:

Pounds per acre N	Pounds per acre P_2O_5	Pounds per acre K_2O	Cane obtained Tons per acre
175	60	50	37.8
"	90	"	40.3
"	120	"	41.5
"	150	"	44.5
"	180	"	44.2

The yield equation obtained from these data is $Y = 47.90 - 18\ (0.75)^x$, in which X is expressed in lots of 30 pounds per acre of P_2O_5. Calculated amounts of phosphoric acid needed for a given tonnage of the crop are:

Tons cane per acre	Pounds P_2O_5 per acre
30	1
35	35
40	86
45	190

Experiment 8, 1922 Crop, potash test:

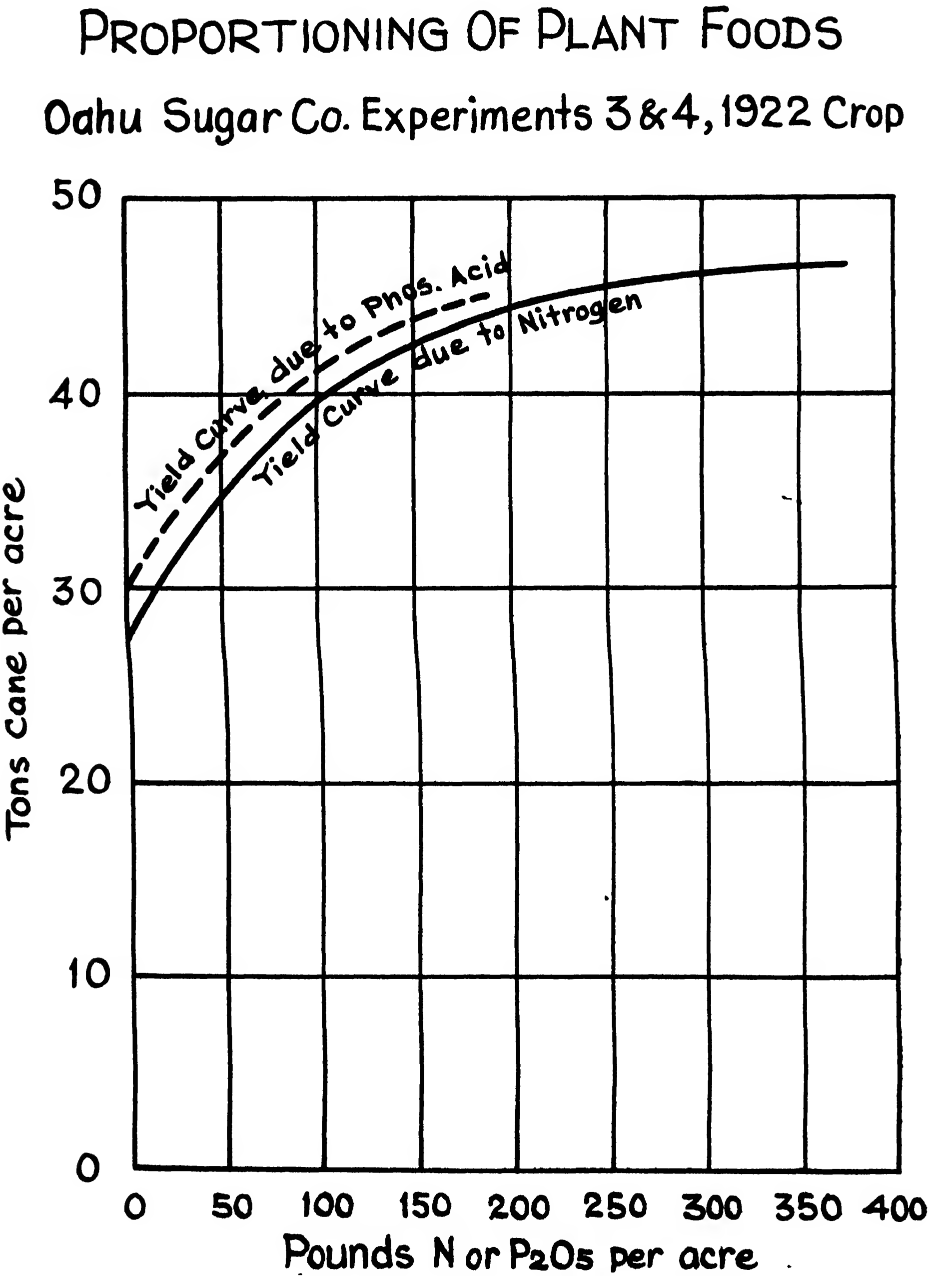
Pounds per acre N	Pounds per acre P_2O_5	Pounds per acre K_2O	Cane obtained Tons per acre
175	120	0	45.8
"	"	100	44.2

The field is evidently rich in potash, hence the question of potash is dropped from further consideration. The other elements required are:

Tons cane per acre	Pounds per acre N	Pounds per acre P_2O_5	Difference $N - P_2O_5$	Ratio $N : P_2O_5$
30	17	1	+ 16	1 : 0.06
35	52	35	+ 17	1 : 0.67
40	107	86	+ 21	1 : 0.80
45	235	190	+ 45	1 : 0.81

The ratio between weights of nitrogen and phosphoric acid necessary to produce a crop varying from 30 to 45 tons per acre is not constant, which fact is not in accord with the accepted view that plant foods in general are demanded by the cane crop in the same proportion, whatever the size of the crop will be.

In this particular field, it seems to be a good practice to apply a little more phosphoric acid than the indicated amount, perhaps equal amounts of nitrogen and phosphoric acid, since the latter does not easily leach out, is cheaper than the



former, and does not affect cane ratio unfavorably. The total amount of the two elements to apply depends on the size of the crop desired.

It is questionable, however, whether or not the size of the crop produced by a given amount of nitrogen with a large excess of phosphoric acid (that is, when nitrogen is the limiting factor), will be the same even when phosphoric acid is also decreased to almost the limiting amount. No experimental data are available at present to answer this question. It is hoped, however, that a series of tests will be run in the near future to clear this point.

Corn Root Rot—A Soil-Borne Disease

A paper under the above title by Valleau, Karraker, and Johnson, in the *Journal of Agricultural Research*, Vol. 33, 1926, contributed from the Kentucky Agricultural Experiment Station, makes reference to Hawaiian investigations on root rot of sugar cane as follows:

A review of the literature on this type of root injury revealed the striking similarity between the sugar-cane root rot described by Carpenter and the root rot of corn produced in either sand or soil pot cultures by the use of either diseased soil or diseased roots. The hyphae and the oospores in diseased roots of corn are strikingly similar in appearance to those pictured by Carpenter, and the similarity suggests a relationship between the two fungi. In a later paper Carpenter showed the morphological similarity of his Pythiumlike fungus to *Pythium Butleri* Subramaniam and *Rheosporangium Aphanodermatus* Edson. Subramaniam, as quoted by Carpenter, found his organism to be parasitic on *Nicotiana tabacum*, *Zingiber officinale*, and *Carica papaya*. In the present studies the writers have found that rotted corn roots produced a rot of tobacco similar in character to the disease produced on corn roots in pot cultures. Although it is too early to draw definite conclusions in regard to the actual cause of corn root rot, there is a strong suggestion that the Hawaiian root troubles and those of corn in the United States may be very similar in nature. The fact that the writers have not obtained a Pythiumlike organism in isolations from rotting roots is not surprising, as Carpenter had considerable difficulty in isolating the organism until a favorable medium was discovered. In 1919, Clinton (Conn. Agr. Exp. Sta. Bull. 222) obtained plants of corn severely affected with root rot, and found, in the pith of the stubble in the vicinity of the nodes, the oospores of a fungus which he identified as *Phytophthora cactorum*, but he was not certain whether it was a Pythium or a Phytophthora. The oospore measurements and appearance of the spores correspond closely with those illustrated in this paper.

Free-hand sections of rotting corn roots grown in infected soil, or in sand cultures inoculated with rotten corn roots, have consistently revealed a large-diameter, generally non-septate organism, and numerous oospores of the Pythium type. The type of injury produced in soil and sand cultures is remarkably similar to the injury to Lahaina cane grown in sick soil and caused by a Pythiumlike fungus. The suggestion is made that corn root rot, other than seedling blights known to be caused by certain seed-borne organisms, is caused by a fungus similar to the fungus causing the cane root rot.

Rooted corn roots added to sand cultures of tobacco are capable of causing a type of injury which appears identical with the so-called brown root rot of tobacco in the field.

H. P. A.

Notes on Pythium Root Rot of Sugar Cane

II

By C. W. Carpenter

In the last number of the *Planters' Record** a series of notes was begun on current investigations of root rot of cane being carried on in the department of pathology.

The idea was advanced therein that logically we must consider the universal failure of the Lahaina type of cane as a specific disease distinct in general from the more or less localized growth failures and root failures of our standard canes which for the present we are considering under the growth failure complex as due to a variety or combination of causes. In these latter growth failures the specific cause of Lahaina failure no doubt plays a part. It was considered that the wide-spread failure of the Lahaina type as a commercial cane could more logically result from a concomitant living cause or a small series of closely related causes than from such a variety or combination of diverse factors.

Seemingly in a class with Lahaina cane so far as root disease is concerned, is the otherwise promising variety E. K. 28, which it is reported is now being replaced in Java with other varieties largely because of its susceptibility to root rot. In Hawaii we have recently noted the utter failure of this variety in one locality as soon as it was planted in the field from the quarantine house. *Pythium aphanidermatum* was the apparent causal factor. This failure of a variety other than Lahaina again indicates the existence of specific root disease, the cause of which we would expect to be a specific living factor of widespread rather than local occurrence.

The Lahaina variety of cane has practically disappeared commercially, but a knowledge of the factors that have brought about its elimination is considered very important, since these same factors may be active now in reducing yields of our standard canes below what they might otherwise be, and possibly their effect is increasing, or is cumulative in nature. However improbable it may appear, we should not overlook the possibility that the conceivable ultimate effect might prove to be somewhat the same as on Lahaina. We therefore continue to investigate the so-called Lahaina root disease in relation to the fundamental problem of root disease of cane in general.

Wherever Lahaina has failed commercially, present standard varieties are resistant to the specific causal factor. Before it was known that *Pythium aphanidermatum* occurred at all on the canes Yellow Caledonia, H 109, and D 1135, in the field, some evidence was obtained experimentally that the resistance of these varieties to this fungus was only relative, not absolute. Later, a few cases of root rot of these varieties were observed in the field, and now we are finding that

* *The Hawaiian Planters' Record*, Vol. XXXII, No. 1, p. 107, 1928.

the occurrence of this fungus in a few rotting roots on these canes is not unusual. In general, so few roots in proportion to the total are injured, that we would not except to note above-ground symptoms. Where definite above-ground symptoms have been observed on these canes, some other factor has appeared more concerned as a primary cause than *Pythium*.

We are, then, concerned with the questions: To what degree are our present commercial varieties affected by root disease? What is the nature of their resistance to *Pythium* and other specific causes of root rot? How permanent is this resistance?

The experimental plantings of Lahaina in the Hilo and Hamakua districts of Hawaii, following twenty to thirty years of successful culture of canes resistant to root diseases, already indicate after a few months' growth that this variety would still be a commercial failure. This demonstrates the persistence of the causal factor. How could it persist except by growth on the cultivated cane either as a saprophyte on already dead tissues or as a parasite on the cane roots in some degree? Possibly it could exist on the roots of an alternate host or grow saprophytically on organic matter in the soil. Whether the resting spores of *Pythium* could remain alive this long can only be conjectured, but the rather frequent observation and isolation of this fungus from the roots of resistant varieties show the probable means of persistence. Whether or not the *Pythium* theory of root rot is of universal application to Lahaina failure, we continue to find this fungus associated with root rot of this cane in Hawaii. We certainly have never found this fungus to be a harmless associate in the interior of healthy roots, though it is true that stools of the resistant canes seldom show marked distress of the aerial portion as a result of the rotting of a few roots by this fungus. It can hardly be considered normal for a plant to lose a varying proportion of its young primary roots as a result of the attacks of *P. aphanidermatum*.

As a working hypothesis we may assume, obviously, that a vigorous and normally watered cane plant can lose a number of roots from time to time without appreciable effect on the above-ground vegetation provided the remaining root absorption area, or dormant root buds in reserve, are sufficient to supply the needs of the stool. We may further assume that normally there is a balance between root absorption area and the size of the above-ground plant, maintained in proportion as the plant grows. Under existing conditions the varieties resistant to root disease then are able to maintain this balance sufficiently well so that the visible portions of the stool remain apparently healthy, while a susceptible variety often finds itself with more stalk and leaves than the reduced absorption area of a crippled root system can maintain in a healthy growing condition. It thrives when the balance is maintained and stops growing with a slight change in balance, i. e., when root area becomes insufficient.

Under this hypothesis certain varieties are resistant as a result of: (1) real resistance of the roots to the entrance of the causal agent of rot; and, (2) more prolific rooting combined with less breaking down of root tissue under attack. Under fluctuating conditions, Lahaina cane sometimes can maintain and sometimes cannot maintain a sufficient root system to balance the rest of the plant growth. This would explain the erratic growth of this cane where it has failed and re-

covered, changing soil conditions in their relation to root extension and root rot having temporarily restored the balance.

Occurrence of Fungi

Fungi other than *Pythium* commonly found present in and about the badly rotted roots are: *Fusarium* species, *Trichoderma* species, *Mucor* species, and several fungi suggesting *Rhizoctonia,* as well as a fungus with conidia in chains resembling *Monilia* or *Spicaria.* Bacteria are omnipresent. Of the above, some of the *Fusaria,* and especially *Rhizoctonia,* may later prove to be important in relation to root rot. The *Mucors* and the *Spicaria* occur rather infrequently. At present the bacteria, most of the *Fusaria, Trichoderma* and *Mucors* appear to be only secondary. Inoculation tests will be necessary to establish their relation to normal roots.

Parasitism of Pythium Species Isolated on Hawaii

Incidental to inspection trips on Hawaii, four *Pythium*-like fungi have been isolated. Of these four, two are *Pythium aphanidermatum,* identical with the *Pythium* previously found parasitic on Lahaina cane roots in inoculation tests. The other two are somewhat different, one forming larger spherical conidia or oogonia, and the other differing in other features.

The two strains tentatively identified as *Pythium aphanidermatum* comprise one from the Lahaina plot at Honokaa, Field No. 6, and one from the plot in Field J-2 at Olaa.

The following table shows the result of inoculation of sterilized Waipio soil with ten strains of *Pythium,* including the above-mentioned four. This inoculation experiment, besides confirming the earlier work on the parasitism of *Pythium* suggests that the strains are somewhat adapted to the soils in which they occur so far as their root parasitism is concerned. One Hawaii strain, No. 36 A 7 A, from Honokaa, proved very destructive to Lahaina cane roots in the sterilized soil from Field E at Waipio, Oahu.

INOCULATION TEST WITH *PYTHIUM* SPECIES

Fungus	Culture No.	Source	Variety	Root Rot ±
P. aphanidermatum	2	Ewa, Field 18B	H 109	+
" "	7	Pathology Plot	E. K. 28	+
" "	9	Waialua, Field 19	H 109	+
" "	10	Maui Agr. Co., Field 87	H 109	+
" "	14	Kailua	Lahaina	+
" "	26B	Waipio, Field E	"	+
" "	36A7A	Honokaa, Field No. 6	"	+
Pythium species	3	Onomea, Field 34	"	—
" "	4	" " "	"	—
" "	$33B_2$	Olaa, Field J-2	"	—

Of those showing negative results, Culture No. 3 does not appear to be *Pythium aphanidermatum.* Culture No. 4 differed from most of the other strains in growing at a lower hydrogen ion concentration in a buffered synthetic medium (pH 4.16).

Possibly this fungus, otherwise not noted to be different from *P. aphanidermatum*, would prove parasitic on a soil similar to the one from which it was collected. Culture No. $33B_2$ also was able to grow on the same medium. It should be noted that the only other of the ten strains growing on the acid medium mentioned was No. $26B_2$ from the nearly neutral soil environment of Waipio, and it was found parasitic.

In the root study boxes of this experiment an observation was made as to the reaction of the roots to the attack of the root rot disease, confirming our supposition regarding the forced development of roots to replace absorption area lost.

We have frequently noticed that stools of Lahaina cane in the presence of the root disease have rather characteristically a set of new white primary roots from the root bands of the lower nodes of the shoots, while it seemed to us that in Lahaina and other canes growing normally, the primary roots, once started, continue to extend, branching into secondaries, tertiaries, etc., and further development of new primaries is rare, possibly not occurring abundantly except as new shoots develop nodes or the cane is ratooned.

In the root study boxes with natural sick soil, as well as in sterilized sick soil which had been subsequently inoculated with *Pythium aphanidermatum*, several crops of these new primaries have grown out, been attacked and destroyed. A crop of new white primaries grew out, remained white and healthy in appearance for several days, reaching a length of three or four inches; after some eight or ten days they showed almost simultaneously the fresh reddish lesions of *Pythium* attack. The roots became more and more yellowish-red to deep red in spotted areas which more or less girdled the root. The next stage was either a softening and final complete collapse to a flaccid condition, or the progress was slower, the color changing to dark red, finally to almost black. The larger primaries often took the former course, while the smaller primaries, secondaries, etc., either developed flaccid tips rather quickly or else remained rather firm if attacked some distance from the tip, the red lesions working through cortex and stele, the color gradually becoming darker to black. Reserve dormant root buds seem to have become exhausted, as extension and root replacement now are by branching of primaries and secondaries, etc.

This successive forced root development, attack, destruction and later replacement has been noticed three times in the present inoculation experiment. To explain this rather simultaneous attack of the whole crop of new primaries, the following seems logical: The roots are attacked by the fungus which is well distributed in the soil soon after they start out from the node or after they reach a definite stage in growth; since the roots start at approximately the same time, the time of infection would be about the same, and with a rather definite incubation period or period of growth in the roots before gross symptoms appear, we would have an apparently simultaneous breaking down of the series of roots.

Notes on Root Rot on the Island of Hawaii

A second and third inspection of the experimental Lahaina plots planted by the Olaa Sugar Company, Ltd., the Honokaa Sugar Company, the Onomea Sugar

Company, and the Pepeekeo Sugar Company, in cooperation with the Experiment Station, was made November 8 to 14, 1927, and January 17 to 21, 1928, respectively.

In general, it may be said that in November the Lahaina was growing more vigorously in all plots than in August. In no case was there a complete failure to grow accompanied by the drying leaves and death of the plants that we have observed with this variety when diseased on Oahu. The plants were green, generally characterized by unevenness in size, and in no case as large and healthy in appearance as a whole as the adjoining canes of other varieties. Individual stools in all plots might have been chosen which would compare favorably in size with resistant commercial canes near by.

Typical rotting of the roots of the *Pythium* type was present in all plots and the fungus *Pythium* was observed microscopically in such roots collected from all the plots. Again both smooth- and rough-walled oospores of *Pythium* type were noted; sometimes one form and sometimes the other predominated. The rough-walled oospores have not developed in pure cultures and their significance is not determined.

The time elapsing between collection of root material on Hawaii and the necessary isolation work when done in Honolulu made it desirable to attempt isolations at Hilo. In this way pure cultures of *Pythium* species were secured from the Lahaina roots at Honokaa, Olaa and Onomea. A considerable collection of other fungi and bacteria was also secured for study.

Normal growth of Lahaina was not found in any of the plots as a whole in January. In portions of the plots, particularly in Field 34 of Onomea plantation in the higher places, and Honokaa plantation, Field 29, in scattered small areas, growth of stools might be considered fair, considering the factors of elevation and time of year. In these mentioned areas stooling was good and fair-sized canes were common. At Pepeekeo Sugar Company, Field 1, somewhat the same conditions were present, here and there nearly normal growth having taken place. It should be remarked, however, that even in these exceptional areas, where possibly normal sized canes had developed, the root systems of stools examined were not strikingly better than those of the near-by small stools. More roots were represented on the large stools and there was a stimulated mat of small feeding roots close to the stool and restricted to a few inches of the surface soil. The poorer stools showed less of this forced root growth, but in general as to root rot of roots present there was not the contrast in root system we would expect. All were uniformly deficient in healthy appearing roots. The typical reddish, softened roots of the *Pythium* type of root rot were present in every case, in greater or less numbers.

It is remarkable that some of these stools have made the growth of cane that they have with the scant root system. It does not seem probable that they can continue to grow unless at times they are able to maintain more roots than we observed. With the slight attachment to the soil, as they become heavier, little wind would be required to uproot them.

In the mauka fields at Olaa, Honokaa and Onomea, we found smaller stools, as would be expected at the higher elevation. At Olaa, Field W, the cane did

not have the dry appearance of the plot in Field J-2. In the center of the area, in a flat place, the stools were closing up, and perhaps normal growth for Lahaina in that locality was approached. Other parts of the plot were decidedly poor, with weak, scattered stools common. Except for the central area, the growth has been poor. There was little change from the time of the November inspection in either of the plots at Olaa.

The lower plot, Field J-2, elevation about 300 feet, still presents the appearance we associate with deficient moisture and insufficient nitrogen, although it had received an unusual amount of rain, even for Olaa. The leaves are pale to yellowish green and rather dried out. Stooling is weak and few stools have any sizable canes yet. The adjoining Yellow Caledonia is growing well in contrast to the Lahaina, which appears to be standing still, a typical example of Lahaina failure.

Manager A. J. Watt raises the question, whether Yellow Bamboo, and later Rose Bamboo, which failed in much the same way as Lahaina, failed from the same cause. They first grew well with two ratoons possible, later with one ratoon, and finally even the plant crop failed completely, like Lahaina.

Notes on the individual plots, with representative photographs, are recorded below.

OLAA SUGAR COMPANY

Plot in Field J-2, Area 1/20th acre.
Planted, May 20th, 1927.
Elevation, about 300 feet.

In November as well as in January, the Lahaina cane in this plot more nearly resembled Lahaina diseased cane as we know it on Oahu, than in any other plot of our series. The stand was of varying sized plants, pale yellow-green in color and of a general unhealthy appearance without strikingly definite symptoms. It was in general only about half the size of the adjoining Yellow Caledonia (the latter is a few weeks older).

Mr. Watt observed that it has the typical appearance of the old type of Lahaina diseased cane. The accompanying photograph, taken November 13, shows the general appearance and size of the Lahaina cane in this plot. (Fig. 1.)

The roots: A medium sized stool was removed and washed. It had a decidedly poor root system. Only one or two healthy roots were found. A fair development of root-band roots had formed, together with a considerable mass of fibrous branches, but all were rotting badly.

A larger stool, which had several nodes, had developed a fairly large root system, now represented by soft, reddened to blackish roots. In fact, in the surface layers of this shallow soil, we found rather more roots represented than the plant would normally be expected to require if the roots all extended normally and functioned. It was apparent that a forced development has occurred in response to the death of the root tips. Neither of the plants examined had any normal primary roots and but few have been developed.

Microscopically: It was noted that the rough-walled oospores previously mentioned were abundant in this material. The smooth-walled oospores of *Pythium*

Fig. 1. Lahaina in Field J-2 at Olaa, six months old. Slightly older Yellow Caledonia at left and in background. This is a characteristic phase of Lahaina failure, according to Mr. A. J. Watt.

aphanidermatum were likewise present. Several pure cultures of *Pythium* were isolated from these rotting roots.

In January, all roots were badly rotted with the *Pythium* type of root rot, except a few new primary roots three or four inches long.

Field W, Sec. "B", Mountain View. Area 1/20th acre.
Planted, May 20th, 1927.
Elevation, 1,000 feet.

This plot is in a shallow soil over stones. In November the surrounding D 1135 was rather uneven and spotty. Compared with this, the Lahaina was not so bad. The Lahaina was of uneven sizes, rather pale and yellowish even for this variety, and many plants were much stunted, some almost dead. Quite a number of plants, however, compared favorably with the near-by D 1135.

One of the better plants removed in November had developed a considerable root system. The short new node roots were often healthy in appearance, but the deeper ranging roots were all soft at the tips, i. e., flaccid. Some of the younger primary roots, which had ranged straight down three or four inches, had a reddened to yellowish translucent appearance previously described in the first report on the plot in Field 33 at Onomea. This is the characteristic appearance of *Pythium* actively attacking the large primary roots near and at the tip, and precedes a breaking down into a soft mass or empty skin.

On a smaller plant the band roots of the seed had developed abundantly with much branching. They appeared to be supplying the plant with its moisture and

nutrients, for the primary roots of the shoot were all reddish-yellow, and breaking down with decay. Judging by the remains, they have rotted off about as fast as formed. Besides several rotted stubs of primary roots from the shoot, there were counted six red to yellow affected roots from the shoot, with two additional, which were of healthy appearance. A stunted D 1135 stool near by showed a few red lesions on the roots, but none definitely of the *Pythium* type.

Microscopically: *Pythium aphanidermatum* was observed to be present.

In January, scarcely a living root could be found on the larger stools in the flat area near the center of the plot. All were rotting with the typical appearance of *Pythium* root rot. Pure cultures of *Pythium* have now been isolated from large, young, primary roots a few inches long and just showing the red coloration of the early stage of *Pythium* destruction.

Honokaa Sugar Company

Field No. 29. Area about ½ acre.
Planted, April 18th, 1927.
Elevation, about 500 feet.

The Lahaina in this plot at Honokaa, Field 29, had improved considerably by November. The plants were still of varying sizes, but all green in general, except such dry lower leaves as were probably due to a rather dry soil. Some stools, however, seemed rather physiologically dry than of the dry appearance we associate with dry soil, i. e., marginal drying and death of tissues at edges of older leaves. By physiologically dry is meant the dryness and lack of normal turgor throughout the whole plant, without death of marginal leaf tissues. Many of the larger plants compared favorably with near-by varieties.

The root systems: One of the larger plants had an extensive root system with possibly a normal amount of fibrous roots. A smaller plant had a restricted root development with few fibrous roots in proportion to the size of the plant. The stele of all the primaries was rotted off at a distance of one foot or less from the stool base.

Considering the appearance of this cane in August with the slow start of many seed pieces at that time, it was evident in November in the dry soils existing that this cane was growing and maintaining about 50 per cent of the growth of adjoining canes. The larger plants were over 6 feet tall.

Microscopically: Both smooth- and rough-walled *Pythium* oospores were seen in quantity in the softened stele of affected roots.

The roots of a small stool as well as those of a portion of a large stool were washed out and examined January 20, 1928. A fair root system was present on both. Some *Pythium* rotted roots were found and these later showed the characteristic features of the fungus when examined with the microscope.

Honokaa Field No. 6. Area about ⅛ acre.
Planted, April 18th, 1927. (Replanted later.)
Elevation, about 1,250 feet.

In November the Lahaina had become better established and both small and large plants had in general grown at a rate comparing rather favorably, consider-

ing the elevation, with the near-by D 1135. With two series of plantings of the Lahaina and an uneven scattered stand, with some plants just getting a start, it was difficult to judge how much of the observed above-ground effect had resulted from the very evident root rot present. This estimation was further complicated by the very uneven, patchy growth of the D 1135 near by.

In both plots at Honokaa it was very evident that some factor was more active on the Lahaina than on the other varieties near by. But in the plot in Field 6, there was not the sharp contrast noted in some of our other plots, not necessarily because the Lahaina was doing so much better than in other localities, but the near-by varieties for comparison were not so strikingly more vigorous than the Lahaina. The largest Lahaina plants were about 3 feet high.

One of the larger plants appeared to have sufficient functioning roots. Root rot was evidenced by the number of short primaries, shrivelled at the tip as if previously flaccid, now dried out and shrunken. The soil was rather dry. This plant appeared to have kept ahead of the root rot by producing roots in the relatively dry soil faster than they were destroyed.

Pythium root rot, though present in both plots at Honokaa, was not very active at the time of observation, possibly owing to rather dry soils; at least not active enough to cause entire loss of roots and drying leaves.

Microscopically: Very numerous rough-walled oospores of the *Pythium* type were noted. A *Pythium* fungus was isolated at Hilo from this material.

In January, it was noted that the roots of the Lahaina in this plot were mostly in the surface soil. But few of them were healthy in appearance. Abundant oospores of *Pythium* were later found in the roots collected.

ONOMEA SUGAR COMPANY

Field 33. Area, about 1/20th acre.
Planted, May 17th, 1927.
Elevation, about 1,200 feet.

The Lahaina cane in this plot was in November in decided contrast in size with the adjoining Yellow Caledonia and the D 1135 across the road. It had a nearly normal green color, however, and the larger plants were stooling and forming joints. Considerable variation in size persists, with many small, weak plants. The larger plants were about 3 feet high.

Here again we saw the correlation between size of plants and healthy and absorbing area of the roots. The larger plants had a few more healthy roots in proportion to rotting root area than the smaller plants. We found in plants of both sizes comparatively few really healthy appearing roots.

The new primaries from the stalk root bands were mostly softened or yellowish-red, translucent to watery in appearance, with only a few of the most recently formed that were normal white in color. Such roots as developed to some length before being attacked were softened to flaccid at the tips, with forced branching. In removing the plants no implements were needed. It seemed that only one or two live roots had to be snapped to pull out the stool. The soil was wet.

Microscopically: While the smooth-walled oospores of *Pythium aphanidermatum* predominated, nevertheless there were a considerable number of the rough-

walled *Pythium* type in association in the rotting tips. The swollen mycelium and prosporangia were also observed.

It was observed in January that the root systems of both large and small stools were badly rotted with *Pythium* root rot. Very few roots on a smaller stool appeared at all healthy. A larger stool had now a fair set of new roots about three inches long, white, and for the most part, healthy; some were already in the first stages of breaking down by *Pythium,* characterized by reddening and girdling. The previous crop of roots as well as some of this set were often but empty sacs or skins or else very flaccid. There were a few fibrous small roots on the larger plant. The fungus *Pythium* was isolated in pure culture.

Field 34. Area, about 1/10th acre.
Planted, May 14th, 1927.
Elevation, about 400 feet.

In November the Lahaina had made considerable growth since the previous inspection in August, but it was still rather uneven in size. It was likewise in marked contrast in size with the adjoining Yellow Caledonia, though the largest and most vigorous Lahaina in any of our plots. Both varieties were rather large, and it was found impracticable to try to show the difference with photographs, since in the Lahaina, scattered plants of the larger sort interfered with the view.

The stools removed showed the same type of diseased-reddened to yellowish roots as in Field 33. The difference was in the number of roots rather than in the relative degree of health. The larger plants had in proportion more roots either healthy or only partially broken down than the smaller plants.

One of the larger plants was removed, the roots washed out and taken to Hilo for photographing. The photograph shows a few healthy new white primaries and a great number that should be white but are reddened. On close inspection these show in the photograph as grayish mottled roots or quite black. On this sized stool the whole root system washed clean should be nearly white, the older roots being somewhat darker, to brown. (Fig. 2.)

Microscopically: The root tips and reddened areas showed plentiful mycelium of *Pythium*. *P. aphanidermatum* was isolated at Hilo.

By January this cane had grown considerably. Portions on high ground had stools nearly as large as the Yellow Caledonia near by. In the center of the plot, a few feet lower, were smaller and poorer stools with little or no stick.

The smaller stools in the lower ground had very poor root systems, most of the roots being rotted off by *Pythium.*

The larger cane, on somewhat higher ground, was quite healthy in appearance and had 10 to 12 joints, the canes being about 1¼ inches in diameter. There was a dense mat of forced development of fibrous roots close to the stools and in the surface layers of soil. There were very few roots below a depth of about six inches. The larger roots were rotted off by *Pythium* and the steles of such roots were soft and red from the same fungus. They broke off very easily.

The fungus *Pythium* was readily found in this material.

Fig. 2. Roots of a Lahaina stool six months old, Field 34, Onomea Sugar Company. At this age all the roots should appear almost white when washed clean. The gray-spotted, mottled and dark-colored appearing roots are in reality various reddened stages of *Pythium* root rot. Even the large white primaries show small red lesions.

PEPEEKEO SUGAR COMPANY

Field 1. Area, about 1 acre.
Elevation, about 100 feet.

In November, this cane was growing fairly well but irregularly, as in all the other plots. It was decidedly smaller in general than the adjoining Yellow Caledonia.

One of the larger plants of the plot was removed and the roots washed out. It had developed a large root system with a considerable mass of fibrous roots. Most of the large, short, young primaries, and the longer ones also, were breaking down badly with *Pythium* rot. Often the young primaries, 3 to 5 inches long, were just empty skins with the interior completely broken down. Others, not so

far gone, were yellowish to red, and water-soaked in appearance. The soil was moist, and Manager Webster reported a heavy rain two nights before our inspection.

This plant appears to have been growing vigorously, but the extensive root system formed had been recently attacked throughout. Above ground, the plants appeared quite healthy, green and fresh, stooling considerably, but below ground they were very unhealthy, since scarcely any absorbing area was functioning.

A smaller plant was also examined. The young roots were mostly rotting, especially at the tips; while the older and longer roots were softened the whole length. Fibrous roots were very few. Reddened cortex roots and softened to completely destroyed steles were characteristic of the root system of this plant.

A photograph was taken to show the uneven growth and contrast in size with the adjoining Yellow Caledonia. (Fig. 3.)

Fig. 3. A corner in the Lahaina plot in Field 1 at Pepeekeo. The Yellow Caledonia in the background is the same age (about six months).

Microscopically: Both the smooth-walled *Pythium* oospores and the rough-walled oospores were observed in large numbers in this material.

In January it was noted that the Lahaina had continued to grow but had not made the showing of the near-by Yellow Caledonia; it was uneven in size, few larger plants approaching at all the size and vigor of the Caledonia.

Both large and small stools had considerable root development, but of this little was healthy. Even the new roots, 5 or 6 inches long, as well as those still shorter, were more or less red rotted with the typical appearance of *Pythium* root disease. Many such young roots were merely empty skins, or sacs of water. Others were

more solid but beginning to be flaccid. Numerous oospores of *Pythium* were readily found in this root material.

Summary of Notes of Inspections of Lahaina Plots on Hawaii

The experimental Lahaina plots of Lahaina cane made in cooperation with the Olaa Sugar Company, Ltd., Honokaa Sugar Company, Onomea Sugar Company, and Pepeekeo Sugar Company, were inspected November 9 to 13, 1927, and January 17 to 21, 1928, for the purpose of making root studies.

In general, the Lahaina had become better established and had a better general appearance than at the time of the first inspection in August. In no case was there a complete collapse of stools with drying up of the plants as we often noted in extreme cases on the island of Oahu. In general, the Lahaina is characterized by uneven-sized plants with no plot as a whole as healthy and vigorous-appearing as the near-by commercial canes.

Typical *Pythium* root rot was very evident in all plots, both in November and January, as soon as the roots were exposed, and the fungus *Pythium aphanidermatum*, or a closely related form at least, was observed with the microscope in diseased roots from all plots. Both smooth- and rough-walled oospores were present.

At Hilo, pure cultures of *Pythium* species were isolated from diseased roots collected at Olaa, Honokaa and Onomea. Several associated organisms of possible significance were isolated for observation.

It is increasingly evident in all of the localities that Lahaina will not succeed commercially after the long period of growth of resistant canes. At Honokaa, under rather dry soil conditions in November, the Lahaina was not so conspicuously in contrast with near-by commercial varieties. However, the root systems were quite heavily infected with *Pythium* root rot and we may anticipate a change with more soil moisture through the winter months.

At Pepeekeo, the Lahaina plants, while uneven in size, appeared to be growing quite vigorously. The large root systems, however, were in an active stage of *Pythium* rot, both in November and January. This underground condition had not yet been reflected in the foliage by definite symptoms of distress.

The management of the plantations concerned in this cooperative root disease study maintain an active interest in these Lahaina plots and are doing everything practicable to give the old favorite variety a fair trial. In some cases they have expressed a keen disappointment in the failure of Lahaina to respond to the modern improved agricultural practices and the resulting improved soil conditions. It is a pleasure to again acknowledge the helpful cooperation extended to us in our root studies.

The Relation Between Soil Treatments and Nematode Attacks to Cane Roots in Central Maui Soils

By Guy R. Stewart, F. Muir, R. H. Van Zwaluwenburg, G. H. Cassidy and Fred Hansson

Previous progress reports from the departments of chemistry and entomology have referred to the growth failure which has occurred in certain small areas of H 109 cane in central Maui. The total acreage of cane land involved in these limited poor spots is comparatively small. Very few of the localities where failure has occurred, exceed one-half acre to two acres in extent. The immediate economic return to be obtained from the improvement of these small tracts of cane land is evidently a minor factor. The points on which we have focussed our attention are, first of all: the question whether this growth failure indicates a decrease in the vitality of the H 109 variety of cane; secondly, is the trouble likely to increase in the fields now affected, or spread to new localities? thirdly, can the poor areas be improved by practical methods of field treatment?

The work of the chemistry department upon this problem has centered upon a study of the chemical character of the soils of typical areas where good cane was growing, contrasted to the soils of the adjacent poor spots. A study of the soluble salts, soil reaction and composition of the displaced soil solutions was carried out by the senior author. The results of this work have shown that the soils of the poor areas were not consistently higher in their content of soluble salts or in alklaline soil reaction than the soils of the adjoining land where good cane was growing. Analyses of the displaced soil solutions showed that the solutions from the good cane soils consistently contained a higher content of potash, but potash salts alone have not been found sufficient to cause a recovery of the H 109 cane growing in the poor spots.

Dr. F. E. Hance made an extended study of the content of replaceable bases in the soils of the good and poor areas. The results of this work have been reported in a previous issue of the *Record* (2). It was found that the soils of the poor areas consistently showed a higher content of replaceable magnesium than was present in the good soils. Laboratory experiments with magnesium salts showed that an excess of this base, combined with the soil in replaceable form, exerted a notably deleterious effect upon tilth, permeability and aeration of the soil, so that cane growth was notably retarded.

F. Muir, R. H. Van Zwaluwenburg and Dr. G. H. Cassidy, of the entomology department, have made extensive studies in the field of the root development of the poor cane contrasted to that of stools of adjoining good H 109 cane. This work has shown that notable root destruction at an early stage of the growth of the cane was associated with this localized growth failure. In many of the poor spots a heavy infestation of *Heterodera radicicola* and *Heterodera schachtii* occurred in the roots of stools in the poor areas. This nematode infestation was

sufficiently intense at times so that it appeared possible that it might be responsible for the greater portion of the root destruction which occurred.

The work of both the chemists and entomologists upon this problem has been carried on in close cooperation. It was not possible from the first investigations, made by either department, to state whether the problem was either purely chemical or biological, or a combination of the two, with the effect of pathogenic soil fungus as a contributory factor. It accordingly appeared desirable to try a series of preliminary soil treatments to see what effect could be produced by remedial measures.

Nematode Treatments on the Mainland and Abroad

A careful survey has been made of the methods of nematode treatment employed with various crops both on the mainland of the United States and in Europe. We shall not attempt to give a detailed resume of all the investigations which have been carried out in this field of endeavor, inasmuch as very few of the methods employed are applicable to cane fields where the land is continuously cropped. We shall, therefore, enumerate briefly the various heads under which such treatments might be grouped.

Soil Sterilization: A partial sterilization of the soil has been used principally with greenhouse soils. Steam has been one of the most effective methods of removing the nematode population, but a wide variety of chemicals have been tried. Among these may be mentioned calcium cyanamid, sodium cyanide used alone and combined with ammonium sulfate, cresol, creosote, crude carbolic acid, ammonium carbonate, copper sulfate, sulfur, and potassium xanthate. Of these chemical reagents, the most favorable reports have appeared regarding the possible field use of calcium cyanamid. Van Zwaluwenburg has reported on the use of several of these materials in Hawaii (7) in connection with his studies of the soil fauna. For the reduction of minute insects similar to *Isotomodes* he found potassium xanthate offered some possibilities. The reduction of soil population, however, was not sufficiently complete to encourage us to believe that nematodes could be controlled in the cane fields by this method.

Catch Crops: The use of catch crops, to which the nematodes are attracted and then killed by pulling up or plowing out the plants, has been tried on both the mainland and abroad. This method is also under trial on pineapple lands in Hawaii. A variation in the method of treatment used by Müller and Molz (4) on sugar beet land, in Germany, is to destroy the catch crop and nematodes by means of a corrosive liquid, such as 30 per cent ferrous sulphate. It is reported that succeeding crops of beets were notably improved by this method of operation. For cane land this procedure has the manifest disadvantage that it involves the loss of a portion of the growing time of one crop, in addition to the expense of the various cultural operations which are involved.

Fallowing: The use of a bore fallow, with a change of the crop grown on the land after such a period, has made a notable reduction in the nematode infestation in a number of mainland experiments. The success of such a method depends on the reported inability of certain species of nematodes to adapt themselves to a

new host plant. This plan has the same disadvantages for sugar lands that have been mentioned in connection with catch crops.

Predatory nematodes: Cobb (1) first proposed that the nematodes might be reduced in a soil by certain predatory nematode species of *Mononchus.* The possibility of cultivating *Mononchus papillatus* and related predators was studied by Steiner and Heinly (5), who concluded that it was possible to grow *Mononchus* in pure cultures. Later, Thorne (6) carried out an intensive investigation of the life history, habits and economic importance of some species of *Mononchus.* He concluded that the *Mononchus* population of a single field was subject to wide fluctuations. Their period of active reproduction was not found to coincide with that of *Heterodera schachtii,* hence the chance of reduction of this harmful species by *Mononchus* was greatly reduced.

Experimental Work

In choosing the materials to be employed in our experiments we were guided largely by the field observations of Muir, in which he had noted the improved root growth that had been found in areas which had received applications of mud press, molasses and organic matter. We, accordingly, chose two soils from widely separated areas of poor cane in central Maui. Sufficient soil was collected from each poor spot to fill fourteen large concrete tubs, 2 feet square and 2 feet deep. Each container held approximately 500 pounds of soil. The following duplicate treatments were installed on each soil: Molasses was applied at the rate of 40 tons per acre; mud press was likewise used at the rate of 40 tons per acre. Lime and phosphate, equivalent to the amounts added in the mud press, were applied at the rate of 1000 pounds per acre of CaO and 1,470 pounds per acre of P_2O_5. Organic matter, derived from composted cane trash, was used at the rate of 70 tons per acre. Sulphur had been employed, previously, in some preliminary field treatments in central Maui, at the rate of 1,000 and 2,000 pounds per acre. No noticeable effect was produced by these amounts. In the meantime, we had seen a statement of Henricksen (3) of Porto Rico that reduction of nematodes was obtained by the above amounts of sulfur. This effect appeared to be ascribed to a change of the soil reaction. In order to obtain a notable change in soil reaction in our experiment, we increased the application to 5 tons of sulfur per acre. We likewise applied "sulphogerm," an inoculated gypsum and sulfur mixture, at the rate of 5 tons per acre.

The above treatments upon the poor soil were contrasted with control tubs of the untreated poor soils and with one tub of poor soil treated with molasses at the rate of 60 tons per acre, and one tub of poor soil subjected to partial sterilization. Duplicate control tubs of soil from adjoining areas of good cane were collected for a further comparison. All the soil treatments were made approximately two and a half months before the tubs were planted. The variety used in both series was H 109. Each tub was planted with two selected top seed pieces, which were thinned to the most uniform plant, soon after germination had taken place.

When the plants had reached a height of approximately one foot, inoculations of cane roots from central Maui, containing *Heterodera* nematodes, were added to all the tubs except those which had received the sulfur treatments. The cane

growth was very backward in the four sulfur tubs and it was decided not to add nematodes. Later observations showed that a sufficient number of nematodes were present in the soil to furnish a heavy inoculation of the roots. All the tubs received a uniform fertilization with mixed fertilizer containing 6 per cent of phosphoric acid, 11 per cent of total nitrogen, and 6 per cent of potash, applied at the rate of 1,000 pounds per acre.

Yields of Cane and Tops at Harvest

The experiment was harvested at the end of five months' growth, as this was approximately the time which we have found it possible to grow cane in tubs of the size employed, and still obtain a normal development of cane and tops. The yield of cane and tops is given in Table I. It will be seen that there was a fairly good agreement between the duplicate tubs. The outstanding result from the harvesting data is the notable increase in cane growth obtained in the tubs which were treated with mud press, molasses and organic matter.

TABLE I

YIELD OF CANE AND TOPS ON TWO SOILS FROM CENTRAL MAUI WITH VARIOUS TREATMENTS FOR NEMATODE CONTROL

Soil from Field 18—Kihei

Tub No.	Character of Soil	Treatment	Yield Grams	Average of Duplicate Treatments
1	Good soil	None	1770	1685
2	" "	"	1601	
3	Poor soil	Molasses—40 tons per acre	3140	3350
4	" "	"	3560	
5	" "	Mud press—40 tons per acre	3797	4223
6	" "	"	4649	
7	" "	Lime and phosphate equal to mud press	2764	2708
8	" "	"	2652	
9	" "	Organic matter—70 tons per acre	3890	4553
10	" "	"	5216	
11	" "	Sulphogerm—5 tons per acre	2440	2605
12	" "	"	2770	
13	" "	Sulphur—5 tons per acre	Dead	
14	" "	"	Dead	
15	" "	Partial sterilization	4009	
16	" "	None	1319	
		Soil from Field 2		
17	Good soil	None	3642	3822
18	" "	"	4002	
19	Poor Soil	Molasses—40 tons per acre	4040	4488
20	" "	"	4936	
21	" "	Mud press—40 tons per acre	4932	4965
22	" "	"	4998	
23	" "	Organic matter—70 tons per acre	5475	6876
24	" "	"	8278	
25	" "	Lime and phosphate equal to mud press	3150	3615
26	" "	"	4080	
27	" "	Sulphogerm—5 tons per acre	3272	3197
28	" "	"	3122	
29	" "	Sulphur—5 tons per acre	2142	1707
30	" "	"	1272	
31	" "	Molasses—60 tons per acre	4432	
32	" "	None	2260	

Examination of Cane Roots

The roots of the stools of harvested cane were examined for nematodes by Cassidy and Van Zwaluwenburg. The detailed results of these examinations are given in Table II.

TABLE II

EXAMINATION OF H 109 CANE ROOTS FOR NEMATODES

Tub No.	Soil	Treatment	Nematodes Found in the Soil, Degree of Infestation: Tylenchus Similis	Heterodera Schachtii	Heterodera Radicicola	Original Root Growth	Condition of Roots at Harvest as Regards Decay
1	Good soil, Fld. 18, Kihei	None	.....	Heavy	....	Good	Fair
2	"	None	.....	Heavy	....	Excellent	Fairly good
3	Poor soil, Fld. 18, Kihei	Molasses—40 tons per acre	.....	Light	....	Very good	Excellent
4	"	"	Light	....	Light	Excellent	Good
5	"	Mud press—40 tons per acre	.....	Very light	....	Very good	Good
6	"	"	Light	Light	Light	Excellent	Fairly good
7	"	Lime and phosphate equal to mud press	Heavy	Heavy	....	Excellent	Poor
8	"	"	Heavy	Heavy	Heavy	Very good	Good
9	"	Organic matter—70 tons per acre	.....	Very light	....	Very good	Excellent
10	"	"	Light	Light	Light	Excellent	Good
11	"	Sulphogerm—5 tons per acre	Heavy	Heavy	....	Very good	Very poor
12	"	"	.....	Heavy	Heavy	Very good	Fair
13	"	Sulphur—5 tons per acre				Dead	
14	"	"				Dead	
15	"	Partial sterilization	.....	Moderate	....	Excellent	Good
16	"	None	Heavy	Heavy	Heavy	Poor	Poor
17	Good soil, Fld. 2	None	Heavy	Heavy	....	Good	Poor
18	"	None	Heavy	Heavy	Heavy	Excellent	Fair
19	Poor soil, Fld. 2	Molasses—40 tons per acre	.....	Moderate*	....	Very good	Good
20	"	"	.....	Very heavy	Very heavy	Excellent	Good
21	"	Mud press—40 tons per acre	.....	Very light	....	Excellent	Excellent
22	"	"	.....	Moderate	....	Very good	Good
23	"	Organic matter—70 tons per acre	.....	Heavy	....	Excellent	Very good
24	"	"	Very few	....	Light	Excellent	Excellent
25	"	Lime and phosphate equal to mud press	.....	Heavy	....	Good	Poor

* Culture 19 roots were likewise found to contain *Mononchus* and *Tylencholaimellus* in moderate numbers.

26	Poor soil, Fld. 2	Lime and phosphate equal to mud press	.....	....	Moderate	Very good	Good
27	"	Sulphogerm—5 tons per acre	.....	Heavy	....	Excellent	Fair
28	"	"	.....	....	Moderate	Fair	Good
29	"	Sulphur—5 tons per acre	.....	One specimen	....	Fair	Excellent
30	"	"	.....	....	....	Poor	Good
31	"	Molasses—60 tons per acre	.....	Moderate	....	Very good	Good
32	"	None	.....	....	Moderate	Fairly good	Fair

The above data may be summarized as follows:

Molasses added to poor soils produced excellent growth, with an absence of decay and a moderate infestation of nematodes, compared with untreated soil.

Mudpress produced roots similar to the molasses treatment on both poor soils. There were a notably smaller number of nematodes present than in the untreated poor soil.

Organic matter produced excellent roots when added to the poor soils. There was only a light infestation of nematodes.

Lime and phosphates: The original root growth was good, but breakdown and decay of the roots occurred later.

Sulphur not inoculated: In one soil the sulphur treatment produced an entire failure of growth; in the other there was a poor development of roots. Nematodes were present, though no inoculation was made with infested roots.

Sulphogerm: The average root growth was good, but the nematode infestation was heavy. These nematodes were brought in the soil, none were added.

Partial sterilization of poor soil: The root growth was better than in the untreated soil.

The general conclusion to be drawn from these observations upon the different treatments is that the best root development corresponded with the improved top growth occurring in part of the cultures. This improvement of root and top growth showed the value of the treatments with molasses, mud press and organic matter.

Examinations of the Soils for Nematodes

Uniform samples of soil from each tub were examined by K. J. Pratt, under the direction of Van Zwaluwenburg. These examinations revealed the entire numbers of nematodes living in the soil outside the cane roots. This would include nematode species which are not harmful to cane plants, as well as those which attack the roots.

TABLE III

EXAMINATION OF SOIL SURROUNDING CANE STOOLS FOR NEMATODES

Tub No.	Soil	Treatment	Nematodes Found in the Soil, Degree of Infestation: Tylencho-laimellus	Prismat-olaimus	Hoplolaimus	Dorylaimus	Mononchus
1	Good soil, Fld. 18, Kihei	None	....	....	....	Heavy	....
2	"	None	Very light	....	....	Heavy	....
3	Poor soil, Fld. 18, Kihei	Molasses—40 tons per acre	....	....	....	Moderate	....
4	"	"	....	....	....	Light	....
5	"	Mud Press—40 tons per acre	....	....	....	Light	....
6	"	"	....	....	....	Light	....
7	"	Lime and Phosphate equal to Mud Press	....	....	Heavy	Light	....
8	"	"	....	....	Heavy	Light	....
9	"	Organic Matter—70 tons per acre	....	....	Heavy	....	....
10	"	"	....	....	Heavy	Light	....
11	"	Sulphogerm—5 tons per acre	....	....	Light	Light	....
12	"	"	....	....	Light	Light	....
13	"	Sulphur—5 tons per acre	....	....	....	....	....
14	"	"	....	....	....	Very light	....
15	"	Partial Sterilization	....	....	....	Moderate	....
16	"	None	....	....	Light	Moderate	Very light
17	Good soil, Fld. 2	None	....	....	....	Fairly heavy	....
18	"	None	....	....	....	Heavy	....
19	Poor soil, Fld. 2	Molasses—40 tons per acre	Very light	Very light	....	Moderate	Heavy
20	"	"	....	....	....	Light	Very light
21	"	Mud Press—40 tons per acre	....	....	Light	Moderate	....
22	"	"	....	....	....	Very light	....
23	"	Organic Matter—70 tons per acre	....	....	Moderate	Light	Very light
24	"	"	....	....	Light	Moderate	....
25	"	Lime and Phosphate equal to Mud Press	....	....	Moderate	Moderate	Very light
26	"	"	....	....	Light	Moderate	One specimen
27	"	Sulphogerm—5 tons per acre	....	....	....	Light	....
28	"	"	....	....	....	Very Moderate	....
29	"	Sulphur—5 tons per acre	....	....	....	Light	....
30	"	"	....	....	....	Light	....
31	"	Molasses—60 tons per acre	....	....	....	Light	Heavy
32	"	Untreated	....	....	....	Moderate	Very light

The detailed results are given in Table III, but the most important conclusions may be summarized by the following observations: The tubs of untreated good soil were found to contain a greater number of nematodes than any of the other soils. The partial sterilization of the poor soil caused a notable reduction in nematode numbers. The heavy applications of sulphur and of "sulphogerm" both caused a definite reduction in the nematode population. *Dorylaimus*, a genus containing several species which attack cane, was the most common nematode found in all the tubs of the series. This variety was reduced in numbers in the sulphur-treated soils.

The slightly more colloidal soil from Field 18, Kihei, when treated with organic matter, or with lime and phosphoric acid, contained large numbers of *Hoplolaimus*. This spear-bearing nematode is often found in enormous numbers in cane soils, but is not known to attack sugar cane root.

The molasses treatments, in the more open, permeable soil from Field 2, appeared to favor the increase of the predatory nematode, *Mononchus*. This suggests an added point in favor of molasses treatments for nematode-infested soils.

Examination of Soil Fauna Other Than Nematodes

Representative portions of soil were collected about three inches below the surface among the roots of the cane at the time of harvest. These samples were examined by Van Zwaluwenburg for soil inhabitants other than nematodes. The most numerous of the minute insects present in the soil were the *Isotomodes*. A few representatives of Pauropoda, Entomobryids, Sminthurids and mites were found in various tubs. The latter organisms were present in such scattering numbers that no consistent conclusion could be drawn as to their presence or absence. It was, however, noted that the sulfur treatments reduced the number of incidental organisms and also the *Isotomodes* present in these tubs. Partial sterilization removed the small insect soil inhabitants and none had found their way into the soil during the growth of the plants. Organic matter caused an appreciable increase of the soil fauna, but in the presence of this adequate food supply, very few cane roots were attacked.

Chemical Changes Produced by Soil Treatments

The chemical changes in the soils produced as a result of the various treatments were studied by Stewart and Hansson. The analyses made upon the soils included the determination of the soil reaction and the composition of the displaced soil solutions. These results are given in Table IV. Determinations were made also of the replaceable bases in the principal treatments.

The first comparison to be made is the difference between the displaced soil solution of the two good and two poor soils. In the case of the soils from Field 18, the poor soil was slightly more alkaline than the soil from the adjoining good portion of the field, but there was no great difference in the content of the principal constituents present in the soil solution of either portion of the field. In the case of the soils from Field 2, the content of most of the major constituents in the two

soils was very similar. There was a slightly higher content of potassium in the soil solution from the good portion of the field, but there were few other consistent differences between the two soils. It should be noted that the good and poor soils in each case were selected only on the basis of the growth of the cane in both areas at the time of the collection of our large samples. It was known that poor places had been present in the same general locations in these fields during previous crops. The exact boundaries of the poor areas could not, however, be definitely established. In other words, it is not absolutely certain that the good portions of the field in the vicinity of the poor areas were certain to produce good cane at all times.

The general similarity of the soils collected as good and poor is shown by the determinations of replaceable bases given in Table V.

The figures for the per cent of replaced bases in both good and poor soils show that both groups of soils contain larger percentages of replaceable sodium and magnesium, in relation to the percentage of replaceable calcium, than is desirable for the best plant growth.

The effect of the various treatments upon the soil reaction and the constituents present in the soil solution was not the same for the two poor soils. This is clearly shown by the changes in the soil reaction which were caused by the addition of sulfur to each soil. The 5-ton per acre application of sulfur caused a toxic acidity of 3.28 pH, and a dangerous concentration of soluble iron and aluminum in the soil from Field 18. The soil from Field 2 was less acid in its original reaction, but there was evidently a larger alkaline reserve in the soil. The reaction developed by the sulfur in this case was pH 4.2, and the amounts of iron and aluminum brought into solution were notably smaller. For the sake of simplicity, we shall summarize the more striking effects of the various treatments upon the two soils.

Molasses: The molasses treatment upon one soil caused a slight decrease in soil alkalinity; with the other soil, there was no change in reaction. The molasses caused a definite increase in soluble organic matter in both soils, an increase in the potash present in the soil solution, and a large increase in the replaceable potash.

Mud press: The mud press treatments caused a smaller increase in soluble organic matter than occurred with molasses. The mud press caused a definite increase in the phosphate content of the soil solution of both soils. The calcium content was slightly changed with one soil and doubled with the other. The magnesium present in the soil solution was increased in one soil but was unchanged in the other. In one soil the potassium content of the soil solution was reduced, as was also the replaceable potassium held in the soil. There was a slight increase in the alkalinity of the soil reaction.

Lime and phosphate: The application of these materials in amounts equal to that supplied by the mud press caused a larger liberation of soluble organic matter than occurred with mud press. There was, however, a smaller increase of phosphates in the soil solution than was caused by mud press. The lime and phosphate gave a greater liberation of soluble calcium and freed more soluble magnesium. There was also an increase of soluble potassium in the soil solution and a corresponding decrease in the replaceable potassium held in the soil. There was no appreciable change in soil reaction.

Organic matter: The heavy application of decomposed organic matter, derived from cane trash, caused a material increase in soluble organic matter. There was an appreciable increase in the bicarbonates present in the soil solution but no material change in any of the major constituents.

"Sulphogerm": The application of this gypsum and sulfur material caused an increase of soluble organic matter. There was likewise a notable increase in the content of soluble calcium, sulphates and magnesium. This material caused a slight increase in the content of soluble potassium in the soil solution and a corresponding decrease in replaceable potash.

Sulphur: The sulphur applications were excessive for plant growth, as we had wished to determine the maximum effect on the soil fauna, including nematodes. We have previously noted the material increase in soil acidity. This acidity acted on all the soil minerals to free material quantities of the major constituents of the soil solution, including a high content of iron and aluminum in one soil and a material increase of these materials in the other.

Conclusions: The foregoing observations upon cane growth, root development, soil inhabitants and chemical changes in the soil as the result of our various treatments can only be regarded as furnishing evidence of a preliminary nature. The indications are, from our chemical examination of the soils, that both the soils classed as being definitely poor and the so-called good soils verge over to the border line of an unfavorable chemical environment, owing to the ratio of replaceable calcium to replaceable magnesium and sodium. Definite improvement in root growth and cane development was caused by applications of mud press, molasses, and decomposed cane trash. A much smaller increase was caused by lime and phosphates equal to the amounts added in the mud press than was given by the mud press itself. This points to the probable influence of the organic content of the mud press as a great factor in its beneficial effect.

Chemical studies of the displaced soil solutions of the treated and untreated soils, as well as the determination of the soil reaction and content of replaceable bases, indicated that an increase in the content of soluble organic matter was the one factor which was common to all three types of treatment which gave the most favorable results. It therefore appears probable that the favorable influence exerted by the mud press, organic matter and molasses, is more largely a biological effect than a chemical one. We are replanting the tubs to determine whether the residual effect of the favorable treatments continues to a second cane crop.

Literature Cited

(1) Cobb, N. A. 1917. The Mononchs, A Genus of Free-Living Predatory Nematodes. Contributions to a Science of Nematology VI. Soil Science 3, No. 5, pgs. 431-486.

(2) Hance, F. E., and Stewart, G. R. 1927. Replaceable Bases in the Soils of Central Maui. Hawaiian Planters' Record, Vol. XXXI, No. 4, pgs. 342-354.

(3) Henricksen, H. C. 1925. Why Does a Soil Become Unsuitable? Some Pineapple Problems. Tenth Article, Agricultural Notes, Porto Rico Agricultural Experiment Station, No. 18, August, pgs. 1-4.

(4) Müller, H. C., and Molz, E. 1921. Catch Plant Methods for Combating Nematodes. Zentbl. Agr. Chem. 50, No. 7, pgs. 262-266.

(5) Steiner, G., and Heinly, H. 1922. The Possibility of Control of Heterodera radicicola and Other Plant-Injurious Nemas by Predatory Nemas, Especially by Mononchus Papillatus. Jour. Wash. Acad. Sci. 12, No. 16, pgs. 367-386, fig. 10.
(6) Thorne, Gerald. 1927. The Life History, Habits and Economic Importance of Some Mononchs. Jour. Agr. Res., Vol. 34, No. 3, pgs. 265-286.
(7) Van Zwaluwenburg, R. H. 1926. Injury to Cane Roots in Hawaii by Soil Animals Other than Nematodes. Reports of the Association of Hawaiian Sugar Technologists, pgs. 18-25.

A Study of the Effect of Nematodes Upon Cane Roots in Sterilized Soils

By Guy R. Stewart and Fred Hansson

In the October *Record* for 1925 (2), a preliminary report was given upon the relative effects of various types of root-attacking organisms upon cane roots. In this first experiment, which was carried out as a joint endeavor by the departments of chemistry and entomology, the root growth of Lahaina cane was compared in the presence and absence of nematodes, small centipedes, and minute snails. One of the soils used was from highly acid land on which Lahaina cane had failed in the early days. The other soil employed was from good land upon which Lahaina cane was growing well. A portion of the tubs of acid soil were treated with lime and phosphates to neutralize the acidity, and a toxic concentration of salts was added to half of the tubs of good soil. It was, therefore, possible to study the effect of the root-attacking organisms upon the plant under conditions which were both favorable and unfavorable for cane growth.

The soils were all subjected to partial sterilization to kill insect and animal life, but still contained the usual flora of fungi and bacteria. The general conclusions drawn from this experiment were that small centipedes and snails did not survive in sufficiently large numbers in our tubs to exercise any great influence upon root development. In partially sterilized soil, toxic acidity and a high concentration of salts were less harmful than is ordinarily the case in the field. Notable root destruction and a stunted top growth were found in all the tubs where free living nematodes, largely *Tylenchus similis,* were added to the soil.

Since the time of this preliminary experiment, our knowledge of the effect of root-attacking organisms has been greatly extended by the work of Muir, Van Zwaluwenburg and Dr. Gertrude Cassidy. Van Zwaluwenburg's reports to the Association of Hawaiian Sugar Technologists in 1926 (3), and 1927 (4) clearly show that the minute spring-tailed insect, *Isotomodes,* is usually the principal factor in causing the small pits which have been commonly noted in cane roots. Under the ordinary conditions of cane culture, where there is an appreciable amount of organic matter in the soil as the result of the partial decomposition of cane trash and cane roots, it was found that the cane plant suffered little apparent damage from the attacks of the *Isotomodes.* Where organic matter was almost entirely

lacking, Van Zwaluwenburg found that the *Isotomodes* might turn upon the cane roots as a principal source of nourishment.

Barnum and Van Zwaluwenburg (1) have carried out a valuable experiment in which they have studied the root destruction of Lahaina cane in the presence of *Isotomodes* and *Pythium* fungus. This work was carried out in sterile soil from the Makiki plots. "The combined attacks of *Pythium* and *Isotomodes* produced more serious effects on Lahaina cane than did either organism separately." The results of such studies point to the necessity of further work in which the definite effect of various root-inhibiting factors is determined, both separately and in combination.

The plantation surveys of nematode conditions in the cane fields which have been carried out by Van Zwaluwenburg and Dr. Cassidy have proven of great value in developing our knowledge of the extent to which these organisms are normally present in cane roots. In general, it may be stated that nematodes do not appear to be, ordinarily, a large factor in the destruction of cane roots over extensive areas of cane land. Under unusual conditions they have increased, temporarily, to a point where their presence may be a menace to the development of a succssful crop. Such is the case in various poor spots of the cane fields of central Maui. A study of the relationship of the various soil conditions to the development of nematodes in the soils of such poor spots appears as a companion article in this issue of the *Record*.

In considering the relationship between soil environment and nematode development it became evident that we possessed practically no information as to the effect which nematodes would have were they present in cane roots, without large numbers of fungi and bacteria present in the soil. In other words, did the cane roots break down as a result of the attacks of the nematodes alone, or was the root destruction the result of the entrance of the fungi and bacteria which accompanied the nematodes?

A cooperative experiment was therefore planned between the departments of chemistry and entomology in which sterilized cane cuttings were to be grown in completely sterile soil. Pure cultures of nematodes were to be added to a portion of the cane plants and the effect upon root development and root destruction would be carefully studied. It should be pointed out that, although the nematodes which were added to the cultures were washed with several treatments of sterile water, they were still contaminated by the presence of some bacteria. The reduction in the numbers of fungi and bacteria present in the soil, though quite large, was not complete, owing to the subsequent contamination from the nematode cultures.

Experimental Work

Two notably different types of soil were chosen for use in our pot cultures. One soil was a heavy, black, clay adobe, from the lower fields of Waimanalo Sugar Company. The other soil was a highly acid red clay loam from the Kaneohe district, upon which Lahaina cane had failed in the early days.

A series of thirty-two pots were filled with each soil. Those containing the Waimanalo soil held 30 pounds of soil and the pots of Kaneohe soil each held 35

pounds of soil. Before sterilization, half the pots of Waimanalo soil were treated with a mixture of salts similar to the residue left by a saline irrigation water in sufficient quantity to cause a concentration of 15,000 parts per million of soluble salts. Half of the pots of Kaneohe soil were treated, at the same time, with sufficient lime and superphosphate to neutralize the unfavorable acidity. In order to avoid contamination, all the treatments were added to the individual pots and the soil was sterilized without further handling. The top of each pot was covered with heavy paper and sets of pots were then subjected to steam sterilization for three hours at 15 pounds pressure upon three successive days. Upon completing the sterilization, a soil suspension was made up in sterile water from portions of each soil drawn from the center of extra jars of soil. Upon plating out these soil suspensions, the sterilized soils are found to be absolutely free from fungi and bacteria. It will be seen that the above treatments left half the pots of each soil with a favorable chemical environment for cane growth, and the other half with a distinctly unfavorable chemical condition. The scheme is summarized in Table I.

TABLE I. TREATMENT OF STERILIZED SOILS

Soil Used	Treatment of Soil	Planted to Lahaina Cane	Planted to H 109 Cane
Kaneohe	None	8 pots	8 pots
Kaneohe	Superphosphate and Lime	8 "	8 "
Waimanalo	None	8 "	8 "
Waimanalo	Salts added	8 "	8 "

Half the pots filled with each soil were planted to Lahaina cane and the other half to H 109. The seed pieces used were one-eye cuttings which were covered at each end with hot sealing wax. In order to reduce contamination to the minimum the cuttings were immersed in a 4 per cent formaldehyde solution for a period of three minutes, then washed in sterile water and planted.

The germination of the seed pieces, under these conditions was very slow, and several replantings were necessary before we obtained growth in all the pots. The later development of the plants was rather deliberate, even though all the cultures were fertilized with sterilized mixed fertilizer applied at the rate of 1000 pounds per acre foot of soil. The mixed fertilizer had the following formula: total nitrogen 12 per cent, phosphoric acid 5 per cent, and potash 10 per cent.

After the plants had reached a height of six inches, a portion of the pots of each of the eight sets were inoculated with pure cultures of three species of root-attacking nematodes. The cultures were isolated and furnished us by F. Muir and Dr. Cassidy, of the entomology department. The three species of nematodes used were *Tylenchus similis, Heterodera schachtii* and *Dorylaimus*.

The plants were grown for a period of approximately six months after the addition of the nematodes. The development of leaf and stalk was very deliberate. The final growth of the plants was comparatively small. There was no essential difference between the size of the plants grown in either the favorable or unfavorable chemical state of each soil. This is shown clearly in the accompanying photograph, which shows the development of four typical pots of Lahaina cane.

Uniform growth of cultures in the presence and absence of nematodes.

The treatments illustrated are as follows:

Pot No. 1, Kaneohe soil, no treatment except sterilization, no nematodes.
Pot No. 2, Kaneohe soil, no treatment except sterilization, nematodes added.
Pot No. 3, Kaneohe soil, sterilized, lime and superphosphates added, no nematodes added.
Pot No. 4, Kaneohe soil, sterilized, lime and superphosphates added, nematodes added.

The growth of the plants in the Waimanalo soil was similar to that of the Kaneohe cultures. No appreciable effect upon the top growth of the plants was noted after the nematodes had been added to the various groups of cultures included in the experiment.

After the period of growth at which the photograph in the illustration was taken, all the pots treated with nematodes were examined by Dr. Cassidy and Mr. Van Zwaluwenburg, and the types of nematodes present in them were tabulated. Comparison plots to which no nematodes had been added were likewise examined. The results of these examinations are given in Table II.

TABLE II

RESULTS OF EXAMINATION BY ENTOMOLOGISTS OF NEMATODE EXPERIMENT WITH STERILE SOIL

Soil	Treatment	Cane Variety	Nematodes Added	Nematodes Found	Root Condition
Waimanalo	Sterilized No Salts	H 109	None	None	Root growth fair.
Waimanalo	Sterilized No Salts	H 109	Tylenchus	Tylenchus	Root growth poor. Typical Tylenchus lesions, little deterioration.
Waimanalo	Sterilized No Salts	H 109	Tylenchus	Tylenchus	Root growth poor. No Tylenchus lesions noted. Roots in fair condition.
Waimanalo	Sterilized No Salts	Lahaina	Heterodera	None	Root growth very poor. No deterioration. No galls.
Waimanalo	Sterilized No Salts	Lahaina	Tylenchus	Tylenchus	Root growth very poor. No deterioration.
Waimanalo	Sterilized Salts added.	H 109	Heterodera	None	Root growth fairly good. No deterioration. A few apical galls.
Waimanalo	Sterilized Salts added.	H 109	Tylenchus	None	Root growth poor. No deterioration.
Kaneohe	Sterilized	H 109	None	None	Root growth fair.
Kaneohe	Sterilized	H 109	Heterodera	None	Root growth fair. No deterioration. No galls.
Kaneohe	Sterilized	H 109	Tylenchus	Tylenchus	Root growth poor. No deterioration.
Kaneohe	Sterilized	H 109	Dorylaimus	None	Root growth poor. No deterioration.
Kaneohe	Sterilized	Lahaina	Heterodera	None	Root growth good. No deterioration. No galls.
Kaneohe	Sterilized	Lahaina	Heterodera	None	Root growth good. A few older roots rotted. No galls.
Kaneohe	Sterilized	Lahaina	Tylenchus	None	Root growth poor. No deterioration. One typical Heterodera gall.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Heterodera	None	Root growth fair. No deterioration. No galls.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Tylenchus	Tylenchus	Root growth fair. No deterioration. No galls or red lesions.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Tylenchus	None	Root growth very poor. No deterioration.
Kaneohe	Sterilized Lime and Superphosphate added.	H 109	Dorylaimus	None	Root growth poor. No deterioration.
Kaneohe	Sterilized Lime and Superphosphate added.	Lahaina	Tylenchus	Tylenchus	Root growth good. No deterioration.
Kaneohe	Sterilized Lime and Superphosphate added.	Lahaina	Tylenchus	Tylenchus	Root growth good. No deterioration.

Several deductions may be drawn from the results given in Table II. It will be seen that in many of the cultures the nematodes had disappeared. This was true of a few of the cultures of *Tylenchus,* but all the cultures in which *Heterodera* and *Dorylaimus* had been added were free from nematodes. None of these two species of nematodes had survived in our pots.

It is undoubtedly true that the conditions of our experiment, in which complete sterility of the soil was achieved at the start, were not the most favorable for plant or animal development. Our plants were grown in closely covered cheesecloth cages to avoid contamination from dust. The only water supplied was sterile water. A small amount of contamination was found to have taken place from a limited number of common molds and bacteria, but this flora was comparatively negligible when contrasted to that originally present in the soil.

A series of ammonification and nitrification tests were carried out on the soils of all the typical cultures, including those with and without nematodes. We found that a few of the soils to which nematodes had been added had been contaminated with nitrifying bacteria. No ammonifying organisms were found in any of the groups of cultures.

It is planned to extend the scope of this experiment at a later date, by the use of additional soils which are more favorable to nematode development. We also hope to obtain the coöperation of the pathologists so that cultures of pathogenic fungi and *Isotomodes,* root-puncturing animals, may be present in part of the pots.

The difficulties of working with these various organisms and maintaining the soils used in anything approaching a sterile condition are very great. In the present experiment a small amount of contamination unquestionably took place, but even so, we feel justified in drawing certain general conclusions from the experiment.

Summary

(1) First and foremost among these conclusions should be placed the fact that none of the three varieties of nematodes multiplied to an appreciable extent when they were placed in contact with cane plants in a practically sterile soil. Under these conditions, only *Tylenchus similis* survived, while *Heterodera* and *Dorylaimus* disappeared. This fact points to the greater vitality and vigor of *Tylenchus similis.*

(2) The root destruction which occurred where nematodes were present in sterile soil was comparatively small. This applied to the cultures in which *Tylenchus* survived as well as to those where *Heterodera* and *Dorylaimus* had been added and probably lived for a time.

(3) The cane growth obtained in the sterile control cultures was smaller than in normal soils, but this moderate growth in the sterile soil was not appreciably reduced by unfavorable chemical conditions of the soil.

(4) Determinations of the sterility of the soil cultures were made at the close of the experiment. It was found that a small contamination with common molds and a few groups of bacteria had occurred. The total numbers present were relatively small.

(5) Further work is required to establish the relationship between root destruction and the presence of nematodes, pathogenic fungi and root-puncturing organisms such as *Isotomodes.*

LITERATURE CITED

(1) Barnum, C. C., and Van Zwaluwenburg, R. H. 1927. The Relation of *Pythium* and the Collembolous Insect, *Isotomodes*, to Growth Failure in Lahaina Cane. Report of Association of Hawaiian Sugar Technologists, pp. 24-29.

(2) Stewart, Guy R. 1925. The Relation of Root Injuries to Root Failure in Lahaina Cane. Hawaiian Planters' Record, Vol. XXIX, No. 4, pp. 400-409.

(3) Van Zwaluwenburg, R. H. 1926. Injury to Cane Roots in Hawaii by Soil Animals Other than Nematodes. Report of Association of Hawaiian Sugar Technologists, pp. 18-25.

(4) Van Zwaluwenburg, R. H. 1927. The Relation of the Collembolous Insect, *Isotomodes,* to Sugar Cane Growth Failure. Report of Association of Hawaiian Sugar Technologists, pp. 21-24.

The Quinhydrone Electrode for Measuring the Reaction of Hawaiian Soils

BY W. T. MCGEORGE

The development of accurate methods for estimating small variations in hydrogen and hydroxyl ion concentration of aqueous solutions and their application to soil analysis has been of great value in the study of soil properties. The so-called pH has become a byword in soil chemistry.

Colorometric and electrometric methods have both found wide application, more so the latter, because of the difficulty often encountered in obtaining a water extract of the soil sufficiently clear for colorometric comparisons. The electrometric method involving the use of the hydrogen electrode also has its limitations. Reducible substances affect its accuracy. The electrode, which must be coated with a film of platinum black, is subject to "poisoning" and its activity and accuracy is affected thereby. In soils of pH 6.0 to 7.5 the effect of the stream of hydrogen upon the CO_2 in the soil suspension will also often introduce an error. Considerable interest has therefore been aroused in the quinhydrone electrode advocated by Biilman in 1920. This method is somewhat of a departure from the hydrogen electrode method, and is unique in its simplicity. By means of the organic compound quinhydrone it is possible to form an electrode which acts similarly to the hydrogen electrode. Quinhydrone is a combination of one molecule quinone, $C_6H_4O_2$, with one molecule hydroquinone $C_6H_4O_2H_2$ and in aqueous solution is highly associated into these two components. An equilibrium is developed such as illustrated in the following equation:

$$C_6H_4O_2H_2 = C_6H_4O_2 + H_2$$

The hydroquinone, in other words, acts as a source of hydrogen. The hydrogen gas stream necessary in using the hydrogen electrode is eliminated. Only clean

platinum electrodes are employed. The poisoning so common where the platinum must be coated with a film of platinum black is thus also eliminated. The preparation of the quinhydrone electrode, as Biilman has stated, is extremely simple and quick and is therefore rapidly coming into general use.

A detailed description of the theory, apparatus and method is not necessary, as a number are available in recent literature. Only a few of the salient points will therefore be mentioned.

A special KCl-HCl half cell—.01 N/HCl : .09 N/KCl—to which a trace of quinhydrone is added (calomel half cell may also be used), is connected by capillarity with a saturated KCl solution, and this in turn by a saturated KCl-agar bridge with the soil water suspension (or other unknown) to which approximately .05 gram of quinhydrone per 25 ccs. has been added and into which the second platinum electrode is dipped, completing the chain. From the difference in potential the pH of the unknown may be calculated—correcting for temperature. The chain has been illustrated diagramatically as follows:

Platinum	HCl .01N KCl .09N Quinhydrone (pH 2.06)	Kcl Saturated	Soil Water Quinhydrone	Platinum

$$pH = 2.06 + \frac{E.\,M.\,F.}{.0001984\ T}$$

The difference in potential as measured by the potentiometer (E. M. F.) is substituted in the preceding equation for calculating the pH.

During the course of some investigations in soil reaction being conducted by the writer, a knowledge of the application of the quinhydrone electrode to Hawaiian soil types was sought. The titration of soil extracts and colloids are, for example, much simpler and more rapid by this method than by the hydrogen electrode. However, on attempting to apply it to Hawaiian soils some difficulties were met which are of interest.

The problems related to the determination of soil pH are still more or less unstandardized. Reference is made primarily to the variation in ratio of soil to water used in preparing the soil for the determination. In many soils there is no variation in pH with the variation in soil water ratio, but in some notably highly alkaline types, soils high in soluble acidity, and the highly saline types, there is considerable lack of uniformity. In the determination of soil pH by the hydrogen electrode ratios of 1 : 3 and 1 : 5 (soil to water) are employed, most reports favoring the latter. One would anticipate that the less water used the nearer would be the approach to actual soil conditions, and it is this point which adds to the value of the quinhydrone electrode. Most reports favor a 1 : 1 ratio where this method is used.

Dilution (increase in water to soil ratio) lowers the buffer action of the soil, increases ionization and hydrolysis of salts and acids, and therefore a decrease in hydrogen ion concentration. The quinhydrone attains equilibrium almost instantly. Occasionally there will be some "drift." This is usually due to the presence of

some substance which disturbs the equilibrium, and this is the principal limitation to the method.

$$C_6H_4O_2H_2 = C_6H_4O_2 + H_2$$

Extensive applications of the method have shown that such soil types have not often been met. Out of a set of seventy-five soil samples employed by Biilman himself, nearly all agreed within .1 pH, seven cases exceeded .2 pH, which is considered ample precision for soil work. The quinhydrone usually gave higher results, but was also often lower than the hydrogen electrode. Recent investigations indicate that a ratio of 1 : 1 for the quinhydrone electrode agrees with a 1 : 5 ratio as determined by the hydrogen electrode. No description of the soil types which show lack of agreement is given.

To give the method a trial on Hawaiian soils, twenty-two widely varying chemical and physical types were chosen with a reaction range of 4.6 to 8.0.

1. A reddish yellow clay loam from Kaneohe district on Oahu.
2. A blackish silty clay loam from Grove Farm, Kauai.
3. A yellowish brown silty clay loam from Lihue Plantation Company.
4. A yellowish silty clay loam from Kilauea Sugar Plantation Company, Kauai.
5. A brown silt loam from Honokaa Sugar Company, Hawaii.
6. A chocolate brown silt loam from Wahiawa, Oahu—a highly manganiferous type.
7. A heavy clay, blackish gray, valley soil from Oahu.
8. A highly organic silty loam from Olaa Sugar Company, Hawaii.
9. A yellow silty clay loam from Kilauea Sugar Plantation, Kauai.
10. A brown silty clay loam from Kilauea Sugar Plantation, Kauai.
11. A yellow silty clay loam from Kilauea Sugar Plantation, Kauai.
12. A red silty clay loam from Kilauea Sugar Plantation, Kauai.
13. A highly organic silty soil from Hawaiian Agricultural Company, Hawaii.
14. A reddish brown silty clay loam from Kilauea Sugar Plantation Company, Kauai.
15. A red clay loam from Waialua Agricultural Company, Limited, Oahu.
16. A brown silty clay loam from Ewa Plantation Company, Oahu.
17. A yellowish brown silty clay loam from Kilauea Sugar Plantation Company, Kauai.
18. A highly saline soil from the Pearl Harbor District, Oahu.
19. A red clay loam, Oahu Sugar Company, Oahu.
20. A red clay loam, Oahu Sugar Company, Oahu.
21. A red clay loam, Oahu Sugar Company, Oahu.
22. A red clay loam, Oahu Sugar Company, Oahu.

Air dry soil samples were used in all cases, and only boiled, distilled water was used in making the soil-water suspensions. Determinations were made on ratios of 1 : 1, 1 : 3, and 1 : 5, with both electrodes. The results are given in the following table, and graphically in Figs. 1, 2 and 3.

TABLE I

Soil No.	Hydrogen Electrode			Quinhydrone Electrode		
	1 : 1	1 : 3	1 : 5	1 : 1	1 : 3	1 : 5
1	4.63	4.65	4.75	4.38	4.81	4.86
2	4.83	4.76	4.95	4.73	5.05	5.03
3	4.88	4.92	5.14	4.80	5.15	5.24
4	4.93	5.14	5.22	4.73	5.22	5.37
5	5.19	5.48	5.61	5.41	5.54	5.58
6	5.61	5.82	6.05	7.28	7.46	7.72
7	4.97	5.76	6.23	6.10	6.26	6.71

8	5.31	5.78	5.68	5.66	5.87	5.83
9	5.42	5.76	5.91	5.68	5.79	5.83
10	5.47	5.76	5.98	5.75	5.92	5.92
11	5.81	6.19	6.37	6.08	6.26	6.30
12	6.12	6.39	6.44	7.20	7.63	...
13	6.32	6.25	6.74	6.60	6.66	6.68
14	6.66	6.79	6.88	6.72	6.85	6.88
15	6.66	6.86	7.15	7.88	8.14	8.06
16	6.96	6.90	7.05	7.16	7.31	7.38
17	6.57	6.88	7.10	6.76	6.96	6.97
18	7.50	7.71	8.01	7.79	8.00	8.14
19	7.81	7.50	7.67	8.02	8.27	8.36
20	7.38	7.42	7.50	8.36	8.48	8.54
21	7.34	7.52	7.45	8.11	8.44	8.36
22	7.25	7.34	7.08	8.11	8.31	8.36

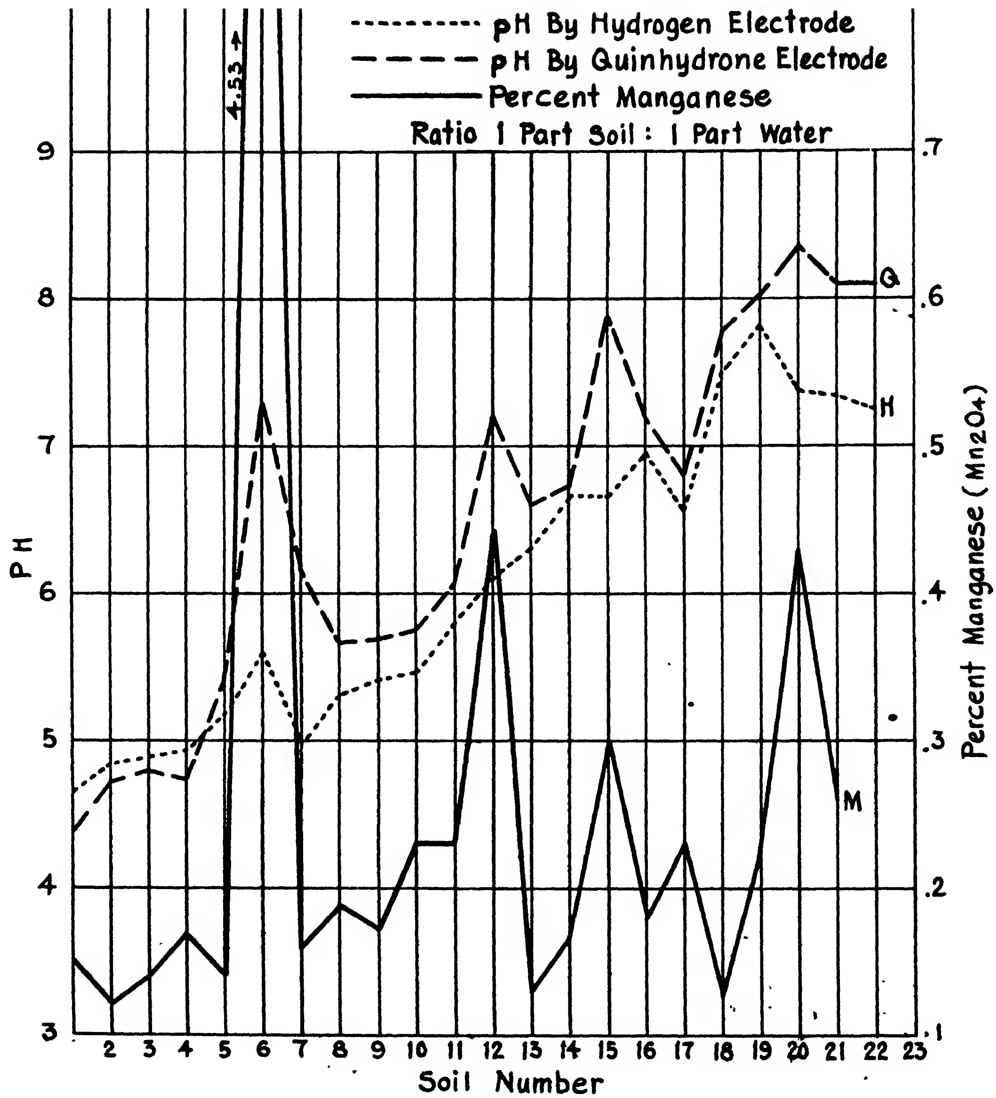


Fig. 1

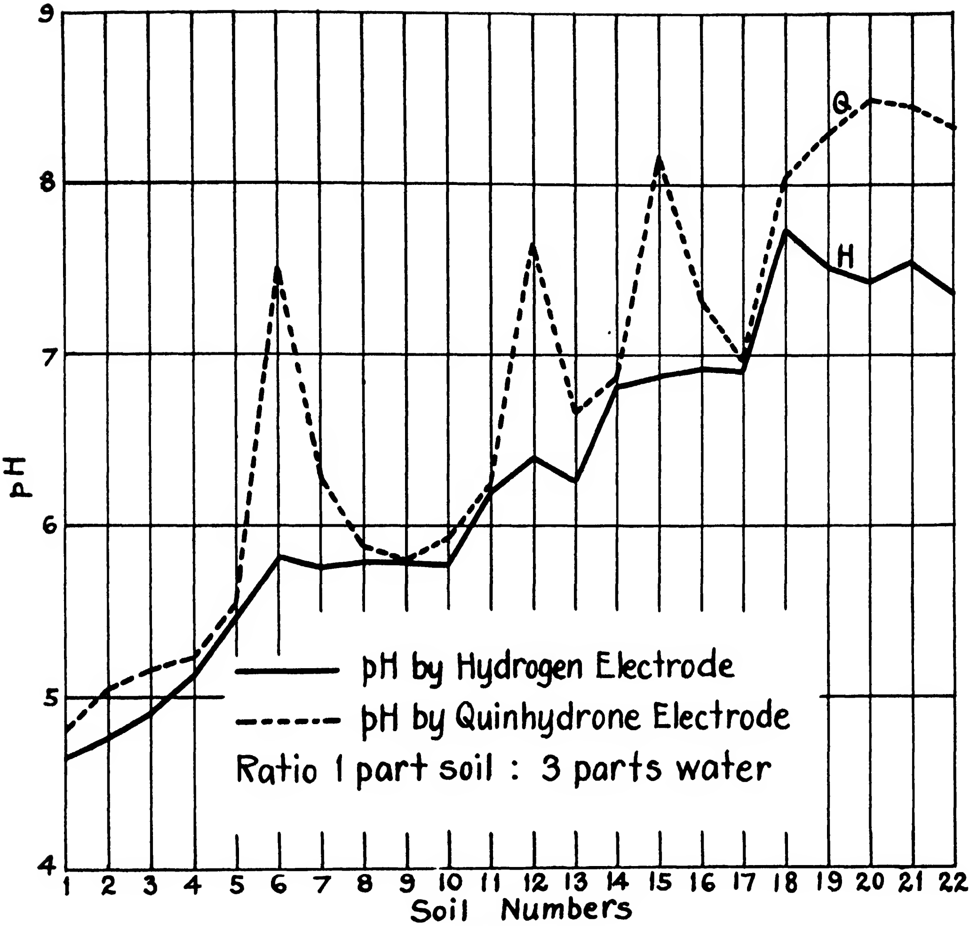


Fig. 2

HYDROGEN ELECTRODE

The data in Table I show a consistent decrease in hydrogen ion concentration with dilution. It appears, therefore, that 1 : 1 ratio more nearly approaches the actual hydrogen ion concentration of the soil. On the other hand, in most cases the differences are within the range of precision allowed for soil analyses. On account of the high absorptive power of many Hawaiian soils for water, it is difficult to get a reading with the hydrogen electrode with a 1 : 1 ratio. And even where the mixture is of sufficient fluidity, the potential is very slow in coming to equilibrium. Soils 7 and 8 are samples of this type. Only one set of readings was taken with this series, and this one hour after preparing the soil-water suspension. For the 1 : 3 and 1 : 5 ratios, readings were taken immediately, one hour after preparation, and five hours after. These results are given in the following table :

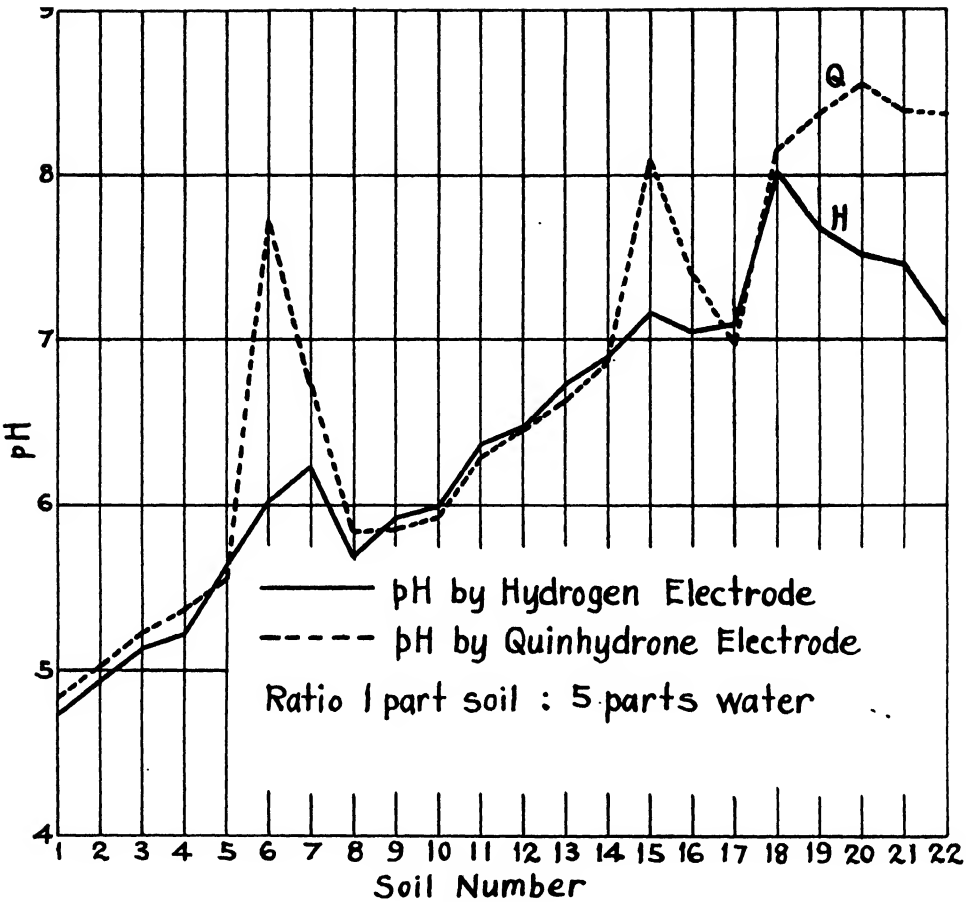


Fig. 3

TABLE II

Soil No.	1:3 Immediate	1:3 1 Hour	1:3 5 Hours	1:5 1 Hour	1:5 5 Hours
1	...	...	...	4.75	4.60
2	4.85	4.76	4.68	4.95	4.94
3	5.02	4.92	4.88	5.14	5.12
4	5.17	5.14	5.09	5.22	4.99
5	5.54	5.48	5.48	5.61	5.58
6	5.71	5.58	5.58	6.05	5.76
7	5.78	5.76	5.68	6.23	6.19
8	5.80	5.78	5.56	5.68	5.68
9	5.88	5.76	5.73	5.91	5.86
10	5.88	5.76	5.78	5.98	5.92
11	6.27	6.19	6.15	6.37	6.25
12	6.45	6.39	6.34	6.44	6.41
13	6.68	6.24	6.57	6.74	6.71
14	6.88	6.79	6.74	6.88	6.88
15	7.00	6.86	6.86	7.15	7.10
16	7.06	6.90	6.83	7.05	6.96
17	7.12	6.88	7.05	7.10	7.05
18	7.79	7.71	7.70	8.01	8.00

These figures show a gradually increasing concentration of hydrogen ion or acidity on standing, and indicate an acid of low solubility or slow rate of hydrolysis.

Quinhydrone Electrode

For the quinhydrone electrode, the soil-water suspensions were prepared one hour in advance, but the quinhydrone added immediately before the determination. Quinhydrone was added at the rate of .025 gram, the whole well shaken, and the reading taken at once. Another .025 gram was then added and another reading taken, this being continued until the reading was constant. That is, until there was no further drift in the potentiometer reading. In most cases .025 gram was sufficient to give the correct and final reading, but in others, notably the manganiferous type, considerably larger amounts were required.

The data obtained by the two methods are of more than passing interest. Sample No. 6 was chosen on account of its high manganese dioxide content. This soil. and also Nos. 12 and 15, gave notably higher pH values by the quinhydrone than by the hydrogen electrode. In view of this, the manganese content of all the soils in the series was determined by extraction with strong HCl (Sp. Gr. 1.115). These results are given in Table III, along with the readings showing the drift in the potentiometer readings, and graphically in Fig. 1.

TABLE III

Gms. Quinhydrone..		.025	.050	.075	.100	.200
Soil No.	Per Cent* Mn_3O_4		(Potentiometer Reading—E. M. F.)			
1	.05	.160	.160	.160	...	...
2	.02	.174	.174	.174	...	...
3	.04	.180	.180	.180	...	...
4	.07	.185	.185	.185	...	...
5	.04	.203	.203	.203	...	...
6	4.53	.170	.200	.250	.280	.315
7	.06	.255	.272	.275	...	...
8	.09	.222	.222	.222	...	...
9	.07	.217	.218	.218	...	...
10	.13	.225	.225	.225	...	...
11	.13	.245	.245	.245	...	...
12	.34	.295	.325	.325	...	...
13	.03	.267	.269	.269	...	...
14	.07	.280	.280	.280	...	...
15	.20	.335	.350	.356	...	...
16	.08	.307	.307	.307	...	...
17	.13	.286	.286	.286	...	...
18	.03	.347	.347	.347	...	...

It will be noted that the soils containing as little as 0.34 and 0.20 per cent oxides of manganese have high potentiometer readings with the quinhydrone electrode. In order to study this point, further manganese dioxide was added to two soils which showed no potentiometer drift to determine what the effect would be. These results are given in the following table and in Fig. 4. They closely correlate the drift characteristic of the three "truant" soils met in the series under study.

* Weighed and expressed as per cent Mn_3O_4 but largely present in the soil as MnO_2.

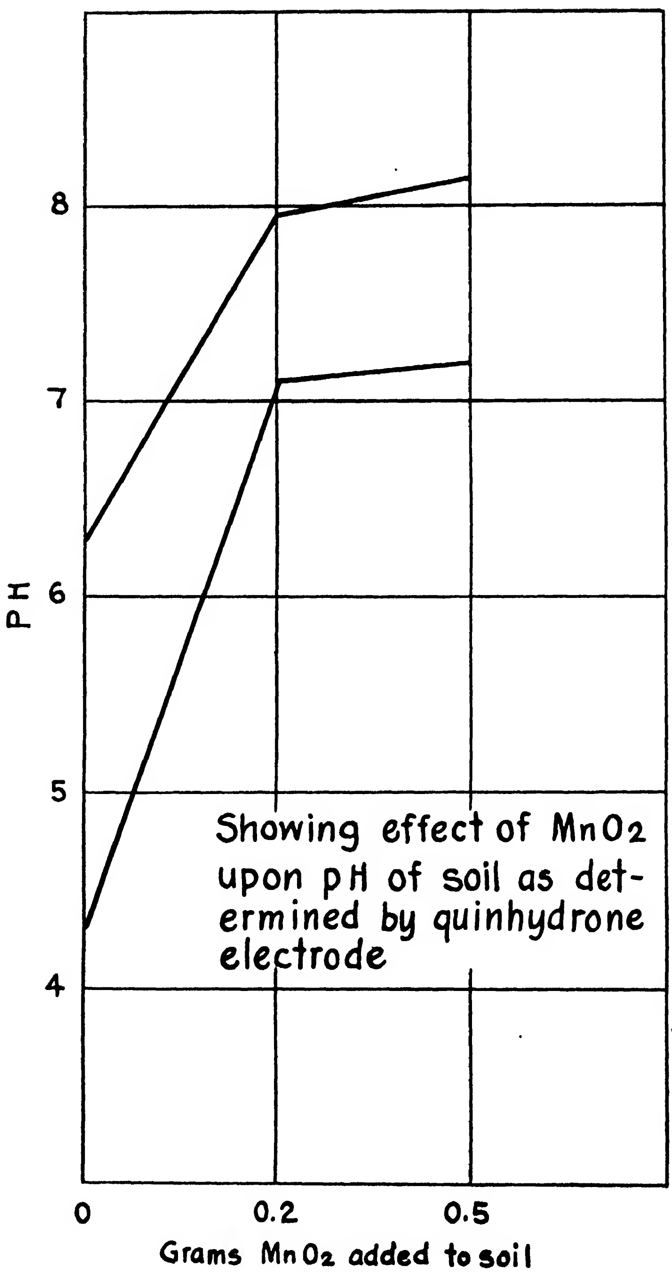

8
7
pH 6
5
4
0
0.2
0.5
Showing effect of MnO2 upon pH of soil as determined by quinhydrone electrode
Grams MnO2 added to soil

Fig. 4

TABLE IV

Potentiometer Readings, E. M. F.

MnO_2 Added	Gms. Quinhydrone	Gms. Quinhydrone	Gms. Quinhydrone	
None	.130	.130	.130	Soil No. 1
.2 gm.	.180	.290	.295	
.5 gm.	.230	.295	.300	
None	.245	.245	.245	Soil No. 2
.2 gm.	.295	.345	.345	
.5 gm.	.320	.360	.355	

The question arising from the above contradiction is, which of the two methods is correct? The conclusion seems inevitable that the quinhydrone electrode is in error if applied to Hawaiian soils containing as little as 0.2 per cent manganese dioxide. This would include most of the red clay loams and red silty loams.

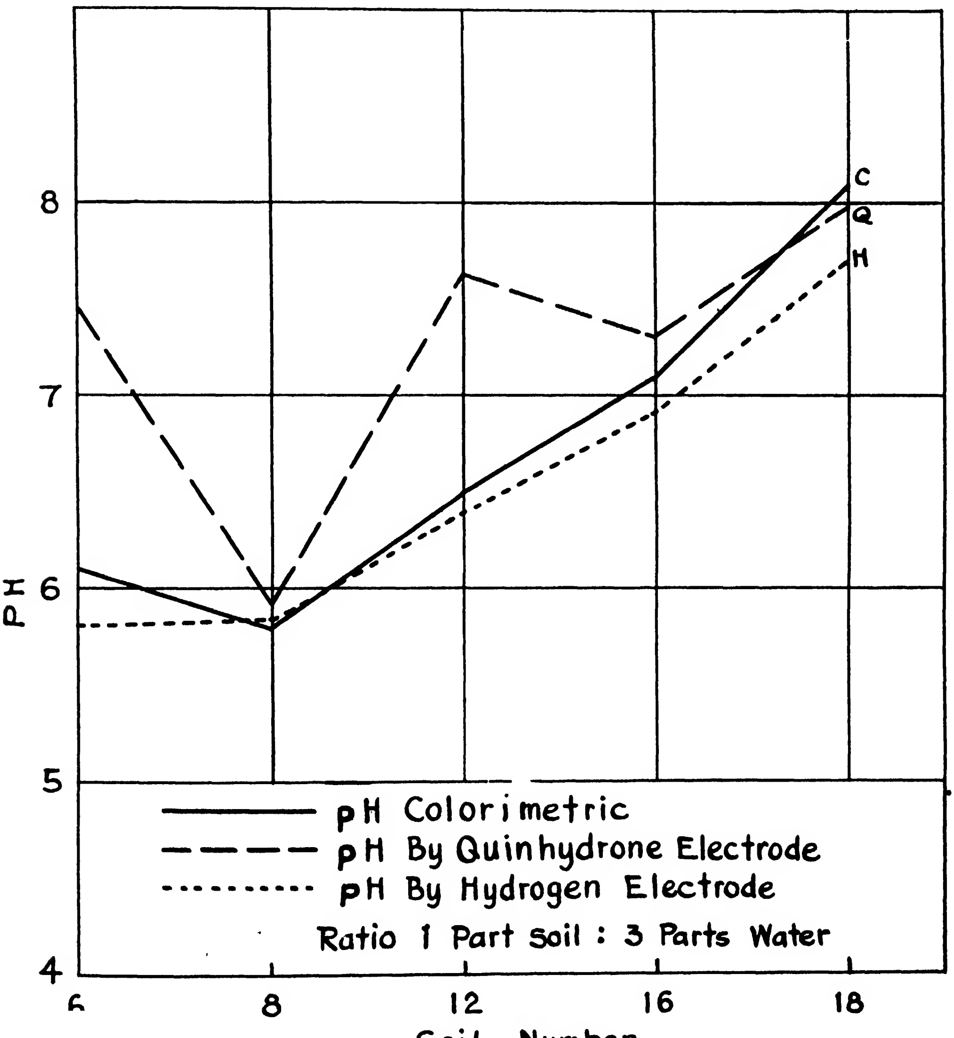


Fig. 5

The colorometric method of determining soil pH values is little influenced by the factors which introduce errors into the quinhydrone and hydrogen electrode methods. It is, however, limited by the difficulty in obtaining a clear water extract without resorting to filtration. Out of the twenty-five soils employed in this investigation, only five would settle sufficiently to give a clear supernatant liquor. The soil pH was therefore determined colorometrically on these five soils. The data compared with the pH as determined electrometrically are shown graphically in Fig. 5. Agreement of all three methods on the nonmanganiferous soils and disagreement on the manganiferous types is shown. Addition of manganese dioxide to these soils and repeating colorometrically and with the hydrogen electrode showed no change in pH values.

Conclusion

The quinhydrone electrode has only limited application for determining the pH values of Hawaiian soils. The presence of manganese dioxide is shown to be a limiting factor and when present in as small amounts as .2 per cent will give high pH values.

In other soil types there is excellent agreement, and in such types the quinhydrone electrode has the advantage in that it is more applicable to a 1 : 1 soil water ratio which most closely approaches the soil water ratio *in situ*. The drift shown by the potentiometer with manganiferous soils is, however, so characteristic as to warn the analyst of the error and thus guards against the reporting of erroneous results. If the potentiometer reading with .05 gram quinhydrone is much higher than with .025 gram, or if the addition of the first .025 gram the potentiometer drifts rapidly downward on standing and before adding the second .025 gram, the soil is unquestionably sufficiently manganiferous to give an error in the reading.

The Terms "Superphosphate" and "Acid Phosphate"

The following letter has been received from The National Fertilizer Association, Washington, D. C.:

Subject: You are asked to use the term "Superphosphate (Acid Phosphate)" instead of "Acid Phosphate."

You will recall that the fertilizer conference which was held at Louisville, Kentucky, September 29 and 30, 1927, upon call of a group of editors of farm papers, and which was attended by agronomists, control officials and members of the industry, voted to refer to the Committee on Definition of Terms of the Association of Official Agricultural Chemists the selection of a less sales-resistant name for acid phosphate. At this conference the name "superphosphate" was preferred.

When the A. O. A. C. held its convention in Washington, October 31 to November 2, 1927, the recommendation of the Committee on Definition of Terms favoring superphosphate with acid phosphate in parentheses, was tentatively adopted, permitting the immediate general use of "Superphosphate (Acid Phosphate)."

The Board of Directors of The National Fertilizer Association at its meeting in Atlanta, November 7, 1927, voted unanimously in favor of "Superphosphate (Acid Phosphate)." The words in parentheses will be used only during the transition period and will then be dropped.

The reasons underlying the strong sentiment in favor of a new name for acid phosphate are numerous. In 1842, Sir John Lawes applied the name superphosphate to the product resulting from rendering phosphorus in bones and in phosphatic rock available for plant food by treating them with sulphuric acid. He then, and always thereafter, applied the name superphosphate to the resulting product. With the exception of the United States, it has become the international, world-wide term.

In the early days of fertilizer use in this country, the name superphosphate prevailed, but in some way we fell into the use of the term acid phosphate. In recent years, coincident with the expansion of fertilizer use in new territory, the name acid phosphate has met with a well-defined sales resistance among farmers who naturally have a feeling against all things acid. Many fertilizer manufacturers are adopting "Superphosphate (Acid Phosphate)" immediately. For uniformity and for the general good of agriculture, it is highly desirable that everyone change to this less sales-resistant form.

H. P. A.

Annual Synopsis of Mill Data—1927

By W. R. McAllep and W. L. McCleery

The 1927 Synopsis contains data for factory operation at all plantations in the Association for the calendar year ending approximately September 30th. These data represent the production of 802,306 tons of sugar. Instances where this calendar year has not coincided with the crop year are shown in the large table, appropriate marks indicating portions of the 1926 crop ground in this period and unfinished 1927 crops.

Data are presented in much the same form as in previous seasons. Factories are listed in the tabulations in the order of the average size of the five preceding crops, except where otherwise noted. The large table is intended as a compilation of polarization rather than sucrose data, though in the last few years it has been necessary to include sucrose data in a few instances where polarization has not been reported. This year, all factories having reported polarization data, no sucrose data are included in the large table except sucrose in final molasses. Sucrose data are again compiled and averaged in a separate table, Number 7. pH and turbidity data are included in the large table. This is the first time these data have been reported from a sufficient number of factories to be included in the Synopsis.

It appears desirable to discuss the significance of small changes in Synopsis averages from season to season because of differences of opinion on this subject. Comments based on relatively small differences in averages of polarization data have been made frequently in the text of the Synopsis and the question has been raised as to whether the figures are of sufficient accuracy for these small changes to be of significance. Also whether small changes in the averages reflect general tendencies or comparatively large differences in results at a few factories.

Mathematically the figures may be considered correct. Data submitted are carefully checked and somewhat elaborate precautions are taken to insure accuracy in calculating and compiling the tables. While errors sometimes occur in handling a large mass of figures even when careful precautions are taken, so far as we are aware very few such errors have occurred in Synopsis figures in the last few years.

From the standpoint of absolute accuracy the figures are not all that might be desired. Available analytical methods are indirect, and within certain limits data must be considered comparative rather than absolute. These differences from the absolute of course result in a corresponding error in the averages, in fact study of these averages gives considerable information on the size of basic errors in factory control methods. For the purpose of studying factory work, however, we are not concerned with the absolute but rather with the comparative accuracy of the averages; that is, to what extent they are comparable from season to season. As a whole, instruments in use and the laboratory personnel do not change to any great extent from year to year. Brix hydrometers are a possible

TABLE NO. 1
MAJOR VARIETIES OF CANE
(One per cent or more of total crop)

	H 109	Y. C.	D 1135	Yellow Tip	Striped Tip	Lahaina	Striped Mexican	Others
H. C. & S. Co.	97	..	..	..	..	..	2	1
Oahu	85	..	14	..	..	..	..	1
Ewa	99	..	..	..	..	..	..	1
Waialua	87	5	7	..	..	..	..	1
Maui Agr.	81	..	..	..	..	10	9	..
Olaa	..	87	13	..	..	..	..	..
Pioneer	86	..	1	..	..	1	10	2
Haw. Sug.	73	3	21	..	..	..	..	3
Lihue	58	22	..	7	..	..	..	13
Onomea	..	85	2	12	..	..	..	1
Honolulu	94	5	1	..	..	..	..	..
Hilo	..	92	6	2	..	..	..	..
Kekaha	66	..	12	..	..	21	..	1
Haw. Agr.	..	41	43	..	..	..	3	13
Hakalau	..	81	1	18	..	..	..	..
Wailuku	80	..	5	..	..	6	6	3
Makee	76	9	..	8	..	..	..	7
Honokaa	3	2	85	..	5	..	..	5
McBryde	71	21	3	..	..	..	2	3
Laupahoehoe	..	38	18	44	..	..	..	..
Hamakua	..	37	52	11	..	..	..	..
Kahuku	88	12	..	..	..	..	..	..
Pepeekeo	..	98	1	1	..	..	..	..
Paauhau	4	3	85	5	..	..	..	3
Honomu	..	96	2	..	..	..	..	2
Koloa	61	14	2	18	..	..	..	5
Waiakea	..	97	2	1	..	..	..	..
Hutchinson	..	60	21	..	..	..	..	19*
Hawi	6	..	38	1	47	..	3	5
Kaiwiki	..	24	20	22	7	..	..	27†
Kohala	1	7	39	14	30	..	..	9
Waianae	100	..	..	..	..	..	..	..
Waimanalo	93	3	3	..	..	..	..	1
Kilauea	13	17	6	42	4	..	..	18‡
Kaeleku	..	100	..	..	..	..	..	..
Union Mill	..	1	21	19	58	..	..	1
Halawa	..	15	25	..	60	..	..	..
Niulii	..	33	30	23	14	..	..	..
Waimea	86	..	..	..	..	14	..	..
Olowalu	78	..	..	..	..	..	22	..
True Average 1927	53.1	23.7	11.8	4.0	1.6	1.4	1.3	3.1
" " 1926	48.7	25.6	12.1	4.5	2.1	1.5	1.5	4.0
" " 1925	42.7	30.7	11.9	2.7	2.1	3.1	2.0	4.8
" " 1924	38.1	32.6	12.0	2.3	2.0	4.4	2.5	6.1
" " 1923	30.7	36.3	11.2	1.2	1.6	8.4	3.1	7.5
" " 1922	21.1	40.3	12.2	2.7	1.6	12.0	2.8	7.3
" " 1921	15.0	45.1	11.0	1.2	1.8	17.4	3.0	5.5
" " 1920	9.1	42.7	10.0	1.4	2.1	26.7	2.5	5.5
" " 1919	6.8	46.4	7.2	0.3	2.6	29.1	1.8	5.8
" " 1918	4.0	42.9	7.5	0.5	1.5	37.9	0.6	5.1

* Rose Bamboo.
† Principally D 117.
‡ Principally Badila.

exception, but even in this case practically all of the hydrometers are calibrated in the same laboratory. Based on a rather conservative estimate of the number of determinations made in a season and the probable size of errors made by men of the class carrying on the work in the laboratories, the usual mathematical methods indicate that the probable error in averages in the large table, due to these factors, does not exceed a few units in the third decimal place. It seems safe to state that differences from season to season due to changes in instruments or in personal error do not have a sensible influence on most of the Synopsis averages.

While factors just discussed should not influence the second decimal place, other factors can have such an influence. Such are, for example, the introduction of new analytical methods, the inclusion of data for the Petree Process, a change such as that at H. C. & S. where the mud was discharged from process at the Kopke separators in 1926 and this season returned to the mill. These can influence averages in the second and even the first decimal place. Such factors are not apparent as a rule on casual examination of the figures. Erroneous deductions may be drawn, however, if allowance is not made for their influence. In so far as possible the influence of all such factors is estimated and taken into consideration in writing the text of the Synopsis. Also before making comments on a particular average, changes at individual factories are tabulated. Examination of this tabulation indicates whether the change in the average reflects a general trend or comparatively large changes at a few factories. The result of this examination is stated when this seems necessary or desirable.

We consider that even small changes in the second decimal place, when data are analyzed as described above, are of considerable significance. While data are analyzed with sufficient care so that statements in the text may be considered substantially correct, deductions drawn from these statements are, to some extent, in the nature of opinions, with which it is entirely possible the reader may not agree. The tables in the Synopsis are prepared with the object of presenting data in as convenient form as possible for reference and analysis. In addition to showing results secured and the trend of factory practice, these data can serve in many instances as a basis of studying the chemical control and the effect of changes in operating methods, averages from year to year for a number of factories affording information that can hardly be secured in any other way. The text is an analysis of the data, written largely for the benefit of readers who cannot spare the time involved in making the necessary comparisons. It can also serve as a starting point for more thorough study of details than is practicable in preparing the Synopsis as a whole, particularly with respect to calling attention to factors influencing the comparative accuracy of the averages, which, if left out of consideration, might result in erroneous conclusions. Without doubt the Synopsis might be greatly improved. In the last year or two we have had the benefit of a number of criticisms and suggestions, several of which have been found practicable and have been incorporated in the Synopsis. Any criticism or suggestions to the end that the Synopsis be made more useful will always be welcome.

Varieties of Cane

The distribution of the major varieties of cane by plantations and the ratio of individual varieties to the total crop for the past ten seasons are shown in Table 1.

The percentage of H 109 has increased to 53.1, a figure more than double that of its nearest competitor, Yellow Caledonia. This is the first time in a considerable number of years that over a half of the cane tonnage has consisted of a single variety. Percentages of all the other major varieties are lower than in 1926. Yellow Caledonia, Striped Tip, Lahaina and Striped Mexican have definitely decreased. However, when the biennial nature of the crop is taken into consideration, an increase is indicated for Yellow Tip instead of the decrease indicated by comparison with 1926 only, and D 1135 is about holding its own. Fluctuations in the proportion of D 1135 during the past eight years have been remarkably small.

The five leading varieties are in the same relative positions as last year. Lahaina, in seventh place last year, has decreased slightly less than Striped Mexican, displacing this variety from sixth place. Rose Bamboo, ranking eighth last year, made up less than one per cent of the crop and so has been dropped from the major variety classification. It now ranks third among the minor varieties.

MINOR VARIETIES

One per cent or more of the crop at any factory

Variety	1924	1925	1926	1927
Badila	.46	.35	.47	.37
U. D. 1	...	...	...	.32
Rose Bamboo	...	...	...	.32
D 117	.49	.52	.15	.25
H 456	...	.11	...	.21
Uba	.03	.11	.10	.13
Kohala Seedlings	...	...	.07	.08
H 20	...	.10	...	.04
W 4	...	...	.02	.04
W 2	...	...	...	.03
H 146	.51	.26	.14	...
Yellow Bamboo	.02	.14	.03	...

Badila continues to hold first place among the minor varieties, though the margin is small. Two new seedlings, Wailuku 2 and U. D. 1, appear for the first time. U. D. 1 has been spread with remarkable rapidity. It is now second in the minor variety classification, with a tonnage amounting to .32 per cent of the total crop, although it is but five years since it was propagated from seed. White Bamboo and H 227 have been dropped from this table, as they have not been reported for two years.

Quality of Cane

Data in Table 2 indicate that the cane has been poorer in quality than in any previous year. On the basis of tons of cane required to make a ton of sugar as

TABLE NO. 2

COMPOSITION OF CANE BY ISLANDS

	Hawaii	Maui	Oahu	Kauai	Whole Group
1918					
Polarization	11.88	14.25	13.50	12.54	12.97
Per cent Fiber	13.35	11.53	12.23	12.84	12.50
Purity 1st Expressed Juice	87.27	88.62	86.93	85.88	87.18
Quality Ratio	9.27	7.73	8.27	8.60	8.47
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Per cent Fiber	13.07	11.74	12.14	12.61	12.49
Purity 1st Expressed Juice	87.54	88.81	87.00	85.82	87.34
Quality Ratio	8.66	7.25	7.81	8.20	8.05
1920					
Polarization	12.86	15.29	13.75	13.07	13.64
Per cent Fiber	13.36	11.39	12.65	12.72	12.64
Purity 1st Expressed Juice	87.87	88.94	85.40	86.52	87.24
Quality Ratio	8.45	7.08	8.07	8.28	8.00
1921					
Polarization	12.25	14.67	13.72	12.67	13.12
Per cent Fiber	13.28	11.82	12.40	13.28	12.80
Purity 1st Expressed Juice	87.18	87.37	85.46	84.07	86.22
Quality Ratio	8.98	7.51	8.11	8.76	8.41
1922					
Polarization	12.07	13.95	13.61	13.03	12.97
Per cent Fiber	13.16	12.38	12.88	13.22	12.95
Purity 1st Expressed Juice	87.17	87.88	86.18	85.80	86.84
Quality Ratio	9.19	7.75	8.04	8.36	8.45
1923					
Polarization	12.09	13.61	12.99	12.94	12.78
Per cent Fiber	13.14	12.01	12.86	12.99	12.82
Purity 1st Expressed Juice	87.61	88.65	85.52	86.58	87.05
Quality Ratio	9.12	7.91	8.50	8.42	8.57
1924					
Polarization	12.44	14.34	13.48	13.34	13.26
Per cent Fiber	12.99	12.16	12.72	12.94	12.74
Purity 1st Expressed Juice	87.98	89.19	87.02	87.31	87.86
Quality Ratio	8.86	7.58	8.16	8.12	8.25
1925					
Polarization	12.35	14.42	13.52	13.24	13.22
Per cent Fiber	12.92	12.40	12.60	12.91	12.74
Purity 1st Expressed Juice	88.02	89.36	87.11	87.19	87.92
Quality Ratio	8.92	7.47	8.18	8.21	8.28
1926					
Polarization	12.53	14.66	13.40	13.03	13.24
Per cent Fiber	12.90	12.24	12.72	12.46	12.65
Purity 1st Expressed Juice	87.59	89.03	86.61	86.68	87.45
Quality Ratio	8.80	7.40	8.29	8.39	8.30
1927					
Polarization	11.34	14.00	12.61	12.07	12.32
Per cent Fiber	12.84	11.98	12.29	12.65	12.49
Purity 1st Expressed Juice	86.27	87.85	85.87	85.17	86.28
Quality Ratio	9.81	7.76	8.86	9.19	8.99

indicated by quality ratio, the decrease in quality corresponds to an increase of almost three-quarters of a ton over that required to make a ton of sugar in 1926, and two-fifths of a ton over that required in 1923; the year which previously held the record for poor cane quality.

The average cane polarization has decreased .92, and the first expressed juice purity 1.17 in comparison with last year. This year's polarization is .46 lower than the previous low point reached in 1923. A slightly lower first expressed juice purity was recorded in one previous season, 1921.

Considering the Islands separately, we find that in each case polarizations and purities are lower and quality ratios higher than in 1926. On Hawaii, Oahu, and Kauai, quality ratios are the poorest on record. On Maui, the quality ratio was poorer in one previous year, 1923.

Data for fiber indicate decreases on Hawaii, Maui, and Oahu, but an increase on Kauai. The average fiber for the crop has decreased .16 in comparison with last season.

Considering data for individual plantations we find that all have reported lower cane polarization and all except one lower first expressed juice purity and poorer quality ratio. Two-thirds of the plantations have reported lower fiber in the cane.

Figures for tons cane per acre for the whole crop and for the five leading varieties are in the following table. These are based on Acreage Census and Annual Synopsis data. Analysis of the discrepancies between these two sets of data indicate that the figures given for tons per acre are probably accurate to within a few tenths of a ton.

TONS CANE PER ACRE

	1925	1926	1927
Crop	53.3	54.4	58.9
H 109	69.4	69.1	73.7
Yellow Caledonia	44.8	45.0	45.1
D 1135	49.3	46.4	46.7
Yellow Tip	41.0	39.8	36.9
Striped Tip	31.5	37.0	30.6

According to the above figures the increase of 4.5 tons of cane per acre for this crop is attributable to heavier yields and larger areas of H 109 and not to an increase in the tonnage of other varieties. Tonnage figures for Striped Tip fluctuate considerably from year to year. Rather than being of general significance these fluctuations reflect conditions in the Kohala district of Hawaii, as some 90 per cent of the Striped Tip is in this district.

Chemical Control

Data for reactions of hot limed juice, clarified juice, and syrup, expressed in terms of pH are included in the Synopsis for the first time. Previously no definite data on juice reactions have been available. The only figure in factory reports having any bearing on this subject has been the amount of lime used. Differences in the amount of lime used in settlings, in the evenness of the liming, in

TABLE NO. 3

True Averages of All Factories Except Those Now Using the Petree Process

	1922	1923	1924	1925	1926	1927
Cane—						
Polarization	12.77	12.66	13.08	12.99	12.99	12.05
Fiber	13.03	12.91	12.82	12.80	12.71	12.55
Tons per ton sugar	8.76	8.68	8.40	8.45	8.50	9.24
Bagasse—						
Polarization	1.71	1.53	1.52	1.54	1.58	1.50
Moisture	41.31	41.29	41.26	41.25	41.09	41.61
Fiber	56.23	56.48	56.74	56.55	56.64	56.20
Polarization % cane	0.40	0.35	0.34	0.35	0.35	0.33
Pol. % pol. of cane	3.11	2.76	2.63	2.69	2.73	2.77
Milling loss	3.05	2.71	2.68	2.73	2.79	2.66
Weight % cane	23.16	22.84	22.59	22.63	22.44	22.33
First Expressed Juice—						
Brix	18.23	17.99	18.34	18.14	18.24	17.17
Polarization	15.79	15.61	16.07	15.91	15.88	14.74
Purity	86.58	86.77	87.61	87.67	87.05	85.84
"Java ratio"	80.9	81.1	81.4	81.7	81.8	81.7
Mixed Juice—						
Brix	13.26	13.11	13.37	13.44	13.65	12.88
Polarization	11.07	11.00	11.31	11.38	11.48	10.67
Purity	83.50	83.87	84.56	84.67	84.12	82.88
Weight % cane	111.65	111.95	112.66	111.03	110.10	109.71
Polarization % cane	12.38	12.31	12.74	12.64	12.64	11.71
Extraction	96.89	97.24	97.37	97.31	97.27	97.23
Extraction ratio	0.24	0.21	0.21	0.21	0.21	0.22
Last Expressed Juice—						
Polarization	1.96	1.73	1.84	1.90	2.06	1.88
Purity	68.66	68.48	71.73	69.63	68.72	67.76
Maceration % cane	34.99	34.79	35.30	33.66	32.54	32.04
Syrup—						
Brix	63.11	63.33	63.18	63.63	64.21	62 91
Purity	84.81	85.40	86.02	85.95	85.49	84.54
Increase in purity	1.31	1.53	1.46	1.28	1.37	1.66
Lime used % cane	0.081	0.085	0.086	0.078	0.083	0.076
Press Cake—						
Polarization	1.96	2.20	2.16	2.17	2.49	2.22
Weight % cane	2.49	2.45	2.45	2.45	2.63	2.67
Polarization % cane	0.05	0.05	0.05	0.05	0.07	0.06
Pol. % pol. of cane	0.38	0.43	0.40	0.41	0.50	0.49
Commercial Sugar—						
Polarization	96.88	96.88	97.20	97.23	97.29	97.40
Moisture	0.85	0.80	0.73	0.74	0.66	0.64
Weight % cane	11.41	11.53	11.91	11.83	11.77	10.83
Polarization % cane	11.06	11.17	11.58	11.50	11.45	10.55
Pol. % pol. of cane	86.94	88.37	88.76	88.78	88.41	87.96
Pol. % pol. of juice	89.69	90.86	91.16	91.24	90.95	90.45
Deterioration factor	0.27	0.26	0.26	0.27	0.24	0.25
Final Molasses—						
Weight % cane	3.14	2.96	2.83	2.82	2.94	3.02
Sucrose % cane	1.07	0.99	0.97	0.93	0.99	1.01
Sucrose % pol. of cane	8.33	7.79	7.45	7.20	7.63	8.37
Sucrose % pol. of juice	8.60	8.01	7.65	7.40	7.84	8.60
Gravity solids	87.94	88.54	89.08	90.09	89.59	89.43
Gravity purity	38.60	37.68	37.81	36.97	37.62	37.40
Undetermined Losses—						
Polarization % cane	0.21	0.11	0.14	0.16	0.13	0.11
Pol. % pol. of cane	1.28	0.65	0.76	0.92	0.73	0.41

the characteristics of different juices with respect to lime requirement and development of acidity, as well as differences in the amount of available CaO in the lime itself, render any inferences based on the amount of lime used most unsatisfactory. Definite data for reaction, expressed as pH values, mark a distinct advance in factory control methods.

The use of pH values brings up the question of how these data should be averaged; that is, whether the figure reported as the average pH should be the average of the pH determinations, or whether it should be the pH corresponding to the average hydrogen ion concentration. After critical examination, in connection with available clarification and control data, we consider that for factory control purposes it is preferable to average pH determinations directly, and pH averages in this Synopsis have been calculated in this way.

Thirty factories have reported pH data. Through a misunderstanding the pH of the cold instead of the hot limed juice has been reported from several factories. These figures have been included in the large table, but have been marked to indicate that they refer to the cold limed juice. They are probably between .1 and .3 higher than it the determinations had been made on the juice after heating. On account of the influence of these figures, this column in the large table has not been averaged.

Turbidity data for clarified juice, determined with the Kopke turbidimeter, are also included for the first time. These data have been reported from 23 factories. In this case also there is some question as to how the averages should be handled, as turbidimeter readings are not in proportion to the amount of suspended matter causing turbidity. Averaging the determinations directly, however, gives a figure which is satisfactory for our purpose and this method of averaging has been used.

Sucrose data have been reported from one additional factory. However, one factory previously reporting sucrose data did not do so this season, leaving the total number the same as in 1926. The thirty factories reporting sucrose data produced 87 per cent of the crop. Gravity solids and sucrose balances for factories reporting the necessary data are in Table 6. Table 7 is a compilation of sucrose data, with true averages for the last two seasons.

There has been no change in the number of factories weighing and measuring the mixed juice. Thirty-six factories report juice weights. The remaining four report weights calculated from mixed juice measurements. Final molasses is weighed at 27 factories, the same number as last season. One additional factory has measured final molasses, bringing the number of factories reporting molasses weights based on measurements to ten. This leaves but three factories reporting neither weights nor measurements.

The usual calculations of recovery on available are in Tables 4 and 5. True sucrose figures in Table 5 should be considered of the greater significance when factories are listed in both tables. During the past few years Synopsis data have reflected a tendency toward higher recoveries on available. This tendency has continued through the past season. Very few low figures are now reported. For instance, there are but four factories reporting under 97 per cent in Table 4 and but three in Table 5. Twenty-three factories report 100 per cent or more on

TABLE NO. 4

APPARENT BOILING-HOUSE RECOVERY

Comparing per cent available sucrose in the syrup (calculated by formula) with per cent polarization actually obtained.

Factory	Available*	Obtained	Recovery on Available	Molasses Produced on Theoretical†
H. C. & S. Co	92.03	92.71	100.7	91.9
Oahu	91.00	92.74	101.9	90.2
Ewa	91.24	91.64	100.4	88.6
Waialua	91.86	90.93	99.0	82.0
Maui Agr	91.79	92.55	100.8	96.0
Olaa	90.79	90.40	99.6	95.7
Pioneer	91.28	92.04	100.8	90.2
Haw. Sug	93.24	94.62	101.5	101.8
Lihue	89.71	91.74	102.3	84.7
Onomea	91.00	91.96	101.1	88.3
Honolulu	89.81	89.23	99.4	86.7
Hilo	91.61	92.29	100.7	90.9
Kekaha	89.75	89.09	99.3	92.8
Haw. Agr	89.58	89.52	99.9	91.0
Hakalau	91.21	92.10	101.0	89.5
Wailuku	90.91	91.36	100.5	92.2
Makee	87.53	89.27	102.0	87.6
Honokaa	88.93	89.72	100.9	91.8
McBryde	91.09	91.25	100.2	94.9
Laupahoehoe	91.78	90.02	98.1	76.5
Hamakua	92.16	91.28	99.0	90.8
Kahuku	90.38	91.40	101.1	84.6
Pepeekeo	91.59	92.10	100.6	91.1
Paauhau	89.83	88.93	99.0	96.5
Honomu	91.53	91.92	100.4	89.3
Koloa	89.71	91.17	101.6	92.2
Waiakea	88.15	87.48	99.2	94.0
Hutchinson	89.58	86.20	96.2	92.4
Hawi	88.56	89.01	100.5	93.7
Kaiwiki	91.07	90.04	98.9	101.4
Kohala	91.19	90.66	99.4	101.0
Waianae	85.88	83.12	96.8	80.7
Waimanalo	88.82	90.74	102.2	83.6
Kilauea	85.54	85.98	100.5	90.0
Kaeleku	85.09	85.30	99.7	81.0
Union Mill	88.21	90.04	102.1	84.7
Halawa	89.56	89.90	100.4	....
Niulii	88.96	87.29	98.1	....
Waimea	89.88	86.80	96.6	....
Olowalu	90.66	83.40	92.0	69.1

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When moisture in sugar has not been reported, the moisture corresponding to 0.25 deterioration factor has been used. 38 has been used when the gravity purity of the molasses has not been reported.

† Gravity solids in syrup, less solids accounted for in commercial sugar considered as theoretical gravity solids in final molasses.

TABLE NO. 5

TRUE BOILING-HOUSE RECOVERY

Comparing per cent sucrose available and recovered

Factory	Available	Obtained	% Recovery on Available	Molasses Produced on Theoretical*
H. C. & S. Co.	92.05	92.07	100.0	91.3
Oahu	91.00	91.84	100.9	84.8
Ewa	91.36	90.56	99.1	89.4
Waialua	91.86	89.75	97.7	86.5
Maui Agr.	91.97	92.00	100.0	98.4
Pioneer	91.32	91.27	99.9	89.2
Haw. Sug.	93.41	93.57	100.2	99.0
Lihue	89.96	90.44	100.5	80.4
Onomea	91.21	91.68	100.5	90.0
Honolulu	90.32	87.73	97.1	94.8
Hilo	91.31	92.18	101.0	87.5
Haw. Agr.	89.80	88.45	98.5	91.5
Hakalau	91.31	91.49	100.2	89.2
Wailuku	90.93	90.76	99.8	91.5
Makee	87.62	88.33	100.8	84.4
Honokaa	88.92	89.35	100.5	95 2
McBryde	91.08	90.68	99.6	96.2
Laupahoehoe	91.28	89.88	98.5	72.5
Hamakua	92.00	91.03	98.9	97.9
Kahuku	90.48	90.34	99.8	83.4
Pepeekeo	91.37	91.88	100.6	89.2
Paauhau	89.74	88.54	98.7	99.2
Honomu	91.55	91.48	99.9	88.9
Koloa	89.62	90.55	101.0	88.1
Waiakea	88.25	86.92	98.5	98.6
Hutchinson	89.44	85.67	95.8	104.8
Waianae	86.24	82.51	95.7	90.3
Waimanalo	88.75	90.14	101.6	77.9
Kilauea	85.75	84.86	99.0	89.8
Olowalu	90.16	82.16	91.1	84.7

* Calculated by the S. J. M. formula.

available in Table 4, against a previous maximum of twenty. Nine of these report over 101 per cent. Thirteen factories report 100 per cent or more in Table 5, against a previous maximum of eleven. One factory only is over 101 per cent in Table 5. There is considerable evidence that much of this general tendency toward higher recovery on available reflects an actual improvement in the work due to closer attention to details in the boiling house, particularly with respect to juice reactions. The accompanying increase in the number of factories reporting in excess of 100 per cent on available has focused attention on several small discrepancies in our control methods. As these have been discussed at some length in the last few Synopses, it does not seem necessary to go into details at this time. However, we would point out that because of these discrepancies the calculated figure for available sucrose is less than the amount of sucrose actually available and that probably slightly in excess of the calculated amount can be recovered in factory practice. Due consideration must be given this factor in analyzing factory operating data. Though data now available are not sufficient to define exactly how much the calculated figure is depressed, it is probably not in excess of one per cent on a true sucrose basis. The instance where over 101 per cent recovery on available has been reported in Table 5 may be considered as due to errors in the control. The nine instances in Table 4 may be considered strongly indicative of such errors.

Tables 4 and 5 also contain data for molasses produced on the theoretical. In Table 4, the theoretical is assumed to be the differences between gravity solids in the syrup and solids accounted for in the sugar. The S. J. M. formula is used for calculating the theoretical in Table 5. Both calculations are valuable for the analysis of control data. Comparisons of the two sets of figures are also of interest, for in the absence of discrepancies in control data differences between them should not be large.

When these molasses calculations were first included in the Synopsis in 1921, the figures were very inconsistent. From year to year since that time there has been an improvement both in the extent to which the less consistent figures vary from the average and in the number of figures varying considerably from the average. This year the average for molasses produced on the theoretical is 91.2; a figure slightly higher than in 1926. A majority of the factories report higher figures than last season.

The deficiencies in control methods, which depress the calculated figure for available sucrose, increase the calculated figure for the theoretical amount of molasses to a considerably greater extent. Averages for molasses produced on the theoretical for the past five years, calculated on the basis of gravity solids in syrup less solids accounted for in the sugar, are between a minimum of 89.2 and a maximum of 91.2 with an average for the five years of 90.5. No doubt conditions at individual factories cause some variation in the amount of molasses produced on the theoretical, but it does not seem as if these variations should be very large, say not in excess of five on each side of the average for all factories. Assuming tentatively that figures for individual factories should be within five of 91.2, the average for this season, we find four factories in Table 4 above and

nine below these limits. It seems reasonably certain that the three high figures indicate errors in control and the low figures, control errors, undetermined losses or both.

Gravity solids and sucrose balances for factories reporting sucrose data are in Table 6. No negative undetermined loss of solids has been reported. One factory has reported a negative undetermined loss of sucrose; an indication of chemical control errors.

A number of comments, based on figures for undetermined loss, have been made in recent Synopses. As opinions on the significance of these figures differ considerably, a discussion of this subject seems desirable.

The undetermined loss purports to be the difference between sugar in the cane and sugar accounted for. Actually it refers to boiling house work only, for up to the time the juice is weighed any factors that would influence it, alter instead the figure for cane polarization. On a sucrose basis the undetermined loss represents mechanical and chemical losses in addition to those determined and reported separately, and the algebraic sum of control errors. On a polarization basis it includes the influence of two other factors. The loss in molasses is reported as sucrose instead of polarization and the ratio of polarization to sucrose is higher in the sugar than in the mixed juice. In both instances the basis on which the sugar is accounted for is relatively higher than the basis on which it is determined in the mixed juice. These factors then depress the undetermined loss below the actual value.

As noted above, the undetermined loss includes the sum of control errors. Weights and analyses are not of absolute accuracy. Just what should be considered a reasonable limit for the sum of unavoidable errors cannot be stated definitely. However, as these errors should be more or less compensating, and mechanical and chemical losses are always sustained to some extent, it seems reasonable to consider a negative undetermined loss on a sucrose basis as evidence of larger than unavoidable control errors. Examination of available data indicates that on a polarization basis figures for undetermined loss are some .5 to 1.0 lower than on a sucrose basis. It is quite probable that a small negative undetermined loss may be indicated by polarization figures in the absence of larger than what may be considered unavoidable errors in the chemical control.

In analyzing data for a single factory, conclusions based on changes in the undetermined loss must be drawn conservatively for such factors as the personal error in weights and analyses, the accuracy of scales, etc., are liable to differ sufficiently from season to season so that this figure is modified by more than a negligible amount. In the case of averages of data from say 40 factories, however, the influence of such factors becomes extremely small and the undetermined loss figure assumes considerable significance. For example, several times in recent years there have been fairly definite indications that boiling house operations have been carried on at more alkaline reactions. Experimental work has shown that this decreases inversion velocities. Under such circumstances a reduction in the Synopsis average for undetermined loss, after examining data to define other factors which might have influenced it, may be considered corroborative evidence that a reduction in inversion loss has been realized.

TABLE NO. 6
GRAVITY SOLIDS AND SUCROSE BALANCES

Factory	Gravity Solids per 100 Gravity Solids in Mixed Juice				Sucrose per 100 Sucrose in Mixed Juice			
	Press Cake	Commercial Sugar	Final Molasses	Undetermined	Press Cake	Commercial Sugar	Final Molasses	Undetermined
H. C. & S. Co.	0.1	82.4	16.1	1.4	0.01	92.09	7.26	0.64
Oahu	5.0	76.4	16.5	2.1	0.64	91.24	7.64	0.48
Ewa	5.6	74.0	17.7	2.7	0.42	90.20	7.72	1.66
Waialua	4.8	75.5	15.6	4.1	0.46	89.33	7.04	3.17
Maui Agr.	...	81.1	18.2	0.7	....	92.00	7.90	0.10
Pioneer	4.4	75.7	17.7	2.2	0.28	90.97	7.74	1.01
Haw. Sug	4.0	80.6	15.4	...	0.40	93.16	6.52	—0.08
Lihue	4.1	73.3	18.6	4.0	0.63	89.91	8.08	1.38
Onomea	4.9	75.5	18.0	1.6	0.16	91.51	7.91	0.42
Honolulu	5.0	72.3	19.6	3.1	0.58	87.22	9.18	3.02
Hilo	4.2	77.3	16.9	1.6	0.33	91.85	7.60	0.22
Haw. Agr.	4.3	73.8	19.8	2.1	0.42	88.14	9.63	1.81
Hakalau	4.2	75.8	18.0	2.0	0.14	91.41	7.76	0.69
Wailuku	3.9	76.6	17.8	1.7	0.39	90.41	8.29	0.91
Makee	4.6	70.7	21.4	3.3	0.59	87.82	10.43	1.16
Honokaa	6.3	70.7	21.3	1.7	0.48	88.95	10.05	0.52
McBryde	3.8	76.0	19.2	1.0	0.23	90.49	8.58	0.70
Laupahoehoe	6.3	77.7	14.4	4.6	0.21	89.66	7.05	3.08
Hamakua	...	80.4	17.8	1.8	....	91.03	7.83	1.14
Kahuku	5.4	71.2	19.5	3.9	0.54	89.83	7.94	1.69
Pepeekeo	6.2	74.1	17.9	1.8	0.28	91.56	7.69	0.47
Paauhau	5.0	72.5	21.5	1.0	0.48	88.15	10.18	1.19
Honomu	4.9	75.7	17.2	2.2	0.24	91.26	7.52	0.98
Koloa	6.5	71.2	20.4	1.9	0.54	90.06	9.14	0.26
Waiakea	5.6	71.3	21.8	1.3	0.67	86.37	11.58	1.38
Hutchinson	6.2	69.6	22.3	1.9	0.24	85.52	11.07	3.17
Waianae	4.1	67.5	23.0	5.4	0.55	82.07	12.38	5.00
Waimanalo	5.3	71.5	19.0	4.2	0.61	89.58	8.76	1.05
Kilauea	3.8	66.2	26.5	3.5	0.86	84.14	12.79	2.21
Olowalu	3.2	67.9	18.8	10.1	0.23	81.96	8.33	9.48

TABLE NO. 7
SUCROSE DATA

Factory	Cane Sucrose*	MIXED JUICE Sucrose	MIXED JUICE Gravity Purity	SYRUP Gravity Purity	SYRUP Increase in Purity	SUGAR Sucrose	SUGAR Sucrose per 100 Sucrose* in cane	Undetermined Loss per 100 Sucrose* in cane
H. C. & S. Co.	14.64	12.40	88.20†	85.21	0.01	97.78	89.67	0.64
Oahu	12.94	11.52	85.21	86.35	1.14	98.11	88.95	0.47
Ewa	12.84	11.10	83.46	85.24	1.78	97.97	88.58	1.63
Waialua	13.23	11.54	85.48	87.00	1.52	97.84	87.05	3.08
Maui Agr.	14.74	12.32	86.88†	87.29	0.41	97.90	89.42	0.10
Pioneer	13.80	12.06	84.34	85.45	1.11	97.94	88.74	0.98
Haw. Sug.	14.45	12.71	87.53	88.38	0.85	97.89	90.71	—0.08
Lihue	11.48	11.21	82.06	83.00	0.94	97.45	87.39	1.35
Onomea	10.99	9.22	83.82	85.40	1.58	97.92	90.18	0.42
Honolulu	13.47	11.33	84.81	86.70	1.89	100.0	84.58	2.93
Hilo	11.29	9.91	84.70	85.98	1.28	97.51	89.97	0.22
Haw. Agr.	11.36	11.40	84.07	85.58	1.51	97.57	85.01	1.74
Hakalau	11.32	9.63	83.89	84.86	0.97	97.29	90.24	0.68
Wailuku	13.57	10.96	85.49	86.30	0.81	97.95	88.86	0.89
Makee	10.69	9.68	82.24	82.70	0.46	97.62	84.07	1.12
Honokaa	10.10	9.43	81.22	83.01	1.79	97.81	85.17	0.50
McBryde	12.95	11.17	84.75	85.74	0.99	97.81	87.62	0.67
Laupahoehoe	12.27	10.05	87.09	87.95	0.86	97.62	87.02	3.08
Hamakua	12.62	11.97	86.68†	87.16	0.48	97.51	88.45	1.11
Kahuku	10.82	9.59	80.86	82.09	1.23	97.91	87.80	1.65
Pepeekeo	11.24	10.09	82.70	84.68	1.98	97.83	89.41	0.46
Paauhau	10.69	9.33	82.86	84.59	1.73	97.69	85.90	1.16
Honomu	11.62	9.80	83.76	85.70	1.94	97.91	89.49	0.97
Koloa	11.49	10.47	80.79	83.00	2.21	98.07	87.10	0.26
Waiakea	11.60	10.65	83.27	85.11	1.84	97.15	82.41	1.31
Hutchinson	10.96	10.88	84.21	85.05	0.84	97.67	81.63	3.03
Waianae	13.08	11.25	82.36	83.49	1.13	97.35	79.46	4.84
Waimanalo	11.10	9.47	80.46	82.25	1.79	97.54	87.87	1.03
Kilauea	10.42	9.84	79.48	79.87	0.39	97.77	81.39	2.14
Olowalu	13.53	11.74	83.26	83.64	0.38	96.93	80.16	9.28
‡True Average 1927	12.46	11.01	84.53	85.86	1.33	97.79	87.96	1.13
" " 1926	13.35	11.68	85.38	86.66	1.28	97.67	88.41	1.20

* Polarization in bagasse and press cake has been assumed to be the same as sucrose in calculating sucrose in cane.
† Clarified juice.
‡ Refinery data from Honolulu not included in averages.

Milling

No new milling machinery installations have been reported this season.

The comparatively large changes in cane quality must be taken into account when comparing mill data with that of last year. With an average cane polarization .92 lower than last year, offset to but a slight extent by a decrease of .16 in the average fiber, it has been necessary to reduce the bagasse to a materially lower polarization to obtain extraction figures approximately those of last season. The changes in cane quality have been quite general.

The average grinding rate is 47.87 tons of cane per hour, an increase of 1.44 over 1926. Although 60 per cent of the factories report higher grinding rates the average tonnage ratio has not increased. With the same tonnage ratio as last year and lower fiber in the cane, the average tonnage fiber ratio has decreased from 22.48 to 22.24. The apparent discrepancy of an increase in the average grinding rate without a corresponding increase in tonnage ratio is because most of the decreases in grinding rates have been at factories with comparatively short rollers, where a given change in grinding rate influences the tonnage ratio to a greater extent than where the rollers are longer. Data from Maui Agricultural Company, a large factory with comparatively short rollers, account for a considerable part of the apparent discrepancy. One tandem was operated at very high capacity at this factory during a considerable portion of the 1926 crop while the other tandem was under construction. With both tandems in operation in 1927 the tonnage ratio was reduced .54, an amount sufficient to make a change of several hundredths in the crop average.

Data for pressure per foot of roller indicate an increase from 67.4 to 68.2 tons. A tendency toward higher pressure has been evident for several seasons.

The tendency toward lower maceration which also has been evident for a number of years has continued. The decrease is from 33.61 to 32.53.

Referring to data for factories which do not use the Petree Process, we find that the difference in purity between first expressed and mixed juice has increased slightly; 2.93 to 2.96. On the other hand, the difference between first expressed and last expressed juice purities has been reduced from 18.33 to 18.08.

Bagasse data indicate an increase of .3 in moisture and a decrease of .19 in fiber. These changes, tending toward an increase in bagasse per cent cane, have been more than offset by the decrease in cane fiber, resulting in a reduction of .22 in the weight of bagasse per cent cane. Bagasse polarization has been reduced from 1.62 to 1.53 and milling loss from 2.88 to 2.73. These averages for bagasse polarization and milling loss are lower than in any previous season except 1921. From the standpoint of extraction, reductions in bagasse per cent cane and in bagasse polarization have not been quite sufficient to offset lower cane polarization, with the result that the average extraction is .02 lower than last year. Although the decrease in the average extraction is small, the tendency toward lower extraction has been quite general. Twenty-five factories report lower extraction against 11 reporting higher.

Considering the milling work as a whole, we find that a slightly smaller proportion of the total sugar in the cane has been extracted. On the other hand,

TABLE NO. 8—MILLING RESULTS

Showing the Rank of the Factories on the Basis of Milling Loss.

Rank	1926 Rank	Factory	Milling Loss	Extraction Ratio	Extraction	Maceration	Tonnage Ratio	Tonnage Fiber Ratio*
1	1	Hakalau......	1.17	0.11	98.70	36.20	1.63	20.15
2	2	Onomea.......	1.26	0.12	98.53	38.86	1.91	24.39
3	3	Waimanalo....	1.65	0.15	98.06	37.45	1.96	23.48
4	4	Hilo..........	1.70	0.15	97.95	35.44	1.80	24.50
5	7	Honomu.......	1.83	0.16	98.06	37.75	1.48	18.16
6	10	Kahuku.......	1.91	0.18	97.71	31.81	1.60	20.42
7	8	Ewa..........	1.98	0.16	98.18	34.91	1.73	20.09
8	6	Wailuku......	1.99	0.15	98.27	41.88	1.16	13.54
9	5	Kekaha.......	2.00	0.15	98.21	28.87	1.77	20.48
10	11	Olowalu.......	2.05	0.16	97.78	36.09	1.66	23.66
11	12	Paauhau......	2.09	0.20	97.42	33.92	1.09	14.16
12	9	Pepeekeo......	2.11	0.19	97.63	29.66	1.68	21.05
13	15	Hamakua......	2.49	0.20	97.16	28.21	1.46	20.89
14	26	Lihue.........	2.55	0.23	97.15	22.80	2.06	26.06
15	13	Oahu.........	2.61	0.20	97.45	32.11	1.86	23.21
16	23	Waialua.......	2.65	0.20	97.41	34.16	2.22	28.31
17	17	Kilauea.......	2.66	0.26	96.68	26.21	1.47	18.86
18	16	Pioneer.......	2.76	0.20	97.52	35.43	2.18	26.77
19	20	Koloa.........	2.80	0.25	96.68	30.34	1.41	18.99
20	21	Laupahoehoe..	2.81	0.23	97.04	40.64	1.66	21.31
21	32	Hawi.........	2.93	0.24	96.74	32.51	1.71	22.86
22	19	Haw. Sug.....	2.97	0.21	97.34	33.14	1.50	19.17
23	18	McBryde......	3.02	0.24	96.79	36.19	1.20	16.37
24	27	Kohala........	3.03	0.25	96.94	43.34	1.61	19.43
25	29	Waimea.......	3.14	0.27	96.77	30.87	1.51	18.27
26	25	Olaa..........	3.16	0.26	96.73	30.32	2.17	26.84
27	22	Haw. Agr.....	3.18	0.28	96.40	18.38	1.88	23.84
28	14	H. C. & S. Co.	3.31	0.23	97.35	35.87	1.69	19.65
29	24	H'onolulu......	3.43	0.26	96.92	36.39	1.68	19.91
30	30	Waianae......	3.43	0.26	96.77	34.20	1.52	18.56
31	31	Honokaa......	3.43	0.35	95.72	24.11	1.64	20.38
32	38	Maui Agr.....	3.48	0.24	97.17	38.77	1.89	22.47
33	28	Makee........	3.60	0.34	95.67	28.80	2.02	25.57
34	33	Kaiwiki......	3.78	0.30	96.15	34.02	1.69	21.48
35	35	Waiakea......	3.80	0.33	95.37	30.17	1.52	21.37
36	34	Kaeleku.......	3.95	0.37	95.00	27.98	1.94	26.31
37	36	Hutchinson....	4.10	0.38	95.42	17.05	2.04	24.66
38	40	Niulii.........	5.08	0.47	93.70	24.89	1.73	22.96
39	37	Union Mill....	5.37	0.49	92.96	24.52	1.72	24.89
40	39	Halawa.......	6.10	0.54	92.65	27.37	1.60	21.62

*Tonnage ratio multiplied by per cent fiber in cane.

the loss of sugar per cent fiber in the bagasse, or "milling loss" has been considerably reduced and the mills have been operated at higher capacity. As the loss per cent fiber in bagasse is a better standard for judging the efficiency of mill operation than the per cent of the total sugar extracted, we consider that as a whole the milling has been more efficient than in 1926.

No factory has equaled the records made in previous seasons for extraction, extraction ratio or milling loss. Seven factories report extractions higher than 98.0 and eight factories report milling loss lower than 2.0. In comparison with 1926 this is a decrease of one in the number of factories reporting higher than 98 extraction and an increase of one in the number of factories reporting under 2.0 milling loss.

Table 8 is a condensed summary of milling results in which the factories are listed according to the size of the milling loss. No changes have taken place in the relative positions of the first four factories. Hakalau is again in first place, followed by Onomea, Waimanalo and Hilo. Lihue and Hawi have improved their relative standing by 12 and 11 places respectively. Waialua, Maui Agricultural, Kahuku and Waimea have also improved their standing materially. H. C. & S. has dropped from fourteenth to twenty-eighth place. Other factories ranking materially lower than last year are McBryde, Hawaiian Agricultural Co., Honolulu and Makee.

Boiling House Work

Clarification: Referring to data in Table 3 for factories which do not use the Petree Process, we find a material improvement in the increase in purity from mixed juice to syrup. The average for this season is 1.66 compared with 1.37 for last year and 1.28 for 1925. Twenty-one factories have reported larger against 13 reporting smaller increases. Figures in the large table for pH of the limed juice indicate that on the whole the juice has been limed to a moderately high pH. After deducting the probable difference between pH of the cold and hot limed juice, where the figures reported are for the juice before heating, we find only a few factories actually within the range where experimental work has indicated the maximum increase in purity is secured. Two-thirds of the factories reporting pH values, however, are within .2 and .3 of this range.

The figure reported for lime consumption has been reduced from .081 to .076 per cent cane, the lowest figure since 1921. In view of the fact that liming as a whole is somewhat below the pH range in which the maximum increase in purity is secured, and that in recent years the size of the increase in purity has fluctuated fairly consistently with fluctuations in the amount of lime used, a larger increase in purity with a smaller figure for lime consumption renders a careful study of factors having a bearing on this point of decided interest.

A decrease in the amount of lime used in settlings would have a tendency in this direction, for, provided the total amount does not exceed the requirement of the juice, better clarification can be secured with a given amount of lime if all of it is added to the juice instead of being divided between the juice and settlings. Though figures for lime used in settlings are not very reliable, such data as are

available do not indicate any material change in this practice in comparison with last season, and it does not seem probable that this factor has influenced the relation of lime used to increase in purity.

Solids in the mixed juice, calculated to per cent on cane, are much lower than in 1926. This can hardly be considered an explanation of the point in question, however, as the lime requirement is a function of the impurities rather than the total solids, and impurities in mixed juice per cent cane are actually higher than in 1926.

The comparatively large changes in cane quality this season may have a bearing on this question. In experimental work on clarification different juices have been found to vary greatly in the amount of precipitable impurities and in lime requirement, although no particular correlation has been observed between purity and these factors; that is, either high or low purity juices may give large or small increases in purity and require large or small amounts of lime. The juices referred to, however, were usually from different areas. In juices from cane grown on the same or similar areas, it does not seem improbable that conditions which cause seasonal changes in certain characteristics of the cane, such as purity and juice density, also tend toward differences in the lime requirement and in the amount of precipitable impurities. No definite information on this point is available at present. When pH data covering a number of years have become available it should be possible to define the effect of seasonal changes on clarification.

There are two factors, however, which have tended toward a low figure for lime and a high figure for increase in purity. These are a change in the way lime is reported and closer attention to juice reactions in the factory. At the beginning of the 1926 season, lime figures on the basis of available CaO instead of total lime were requested. A considerable number of factories reported on this basis, rendering the 1926 figure for lime consumption low in comparison with those for previous years. An additional number of factories, though not all, have changed to the available CaO basis this season. Also hydrated lime has been used much more extensively this season, and usually this has been reported on the basis of 65 per cent available CaO, although hydrated lime supplied locally is much nearer 70 per cent available than 65. The 1927 lime figure is thus low in comparison with 1926, and considerably low in comparison with previous years. Attention has been focused to a considerable extent on irregularities in liming during the past few seasons, particularly since pH determinations have been included in the control, and considerable improvement is being made in this respect. Liming to an even pH, provided the amount of lime used does not exceed the lime requirement, will give a better increase in purity with the same amount of lime than if the pH of the juice is irregular.

pH data as previously noted indicate that on the whole the juice has been limed to a fairly high pH. While we have no data on which to base direct comparisons with previous seasons, observations during factory visits give us considerable reason for believing that the pH is higher than in the past. The reduction in undetermined loss is an indication in this direction, as a reduction in inversion losses, tending toward a reduction in the undetermined, should accompany a higher pH in clarification.

The above indicates that the reduction, if any, in the amount of lime used, is less than would be inferred from reported figures. It is also probable that closer attention to juice reaction has brought about more even liming, thus obtaining a higher average pH with a given amount of lime. We consider that the larger increase in purity is because the juice has been limed to a higher pH. Possibly changes in the character of the juice with respect to lime requirement and the amount of precipitable impurities have been contributing factors, but on this point no data are available at the present time.

Although first expressed juice purity is 1.17 lower than in 1926 and the decrease from first expressed to mixed juice purity slightly larger than last season, the larger purity increase in clarification has resulted in a syrup but .91 lower in purity than last year. Better results in clarification have reduced the difference between the first expressed juice and syrup purity from 1.67 to 1.41. This difference is smaller than in any except three of the previous seasons for which averages are available, and approximates the figure attained in these three seasons, 1914, 1918, and 1923. Available data on this point are tabulated below for reference.

PURITY DECREASE—FIRST EXPRESSED JUICE TO SYRUP

1914	1.40	1921	2.32
1915	1.65	1922	1.88
1916	1.52	1923	1.40
1917	1.66	1924	1.54
1918	1.40	1925	1.65
1919	1.64	1926	1.67
1920	2.04	1927	1.41

Filter Presses: Referring to data in Table 3 we find that the polarization of the press cake has been reduced from 2.49 to 2.22 and that the amount of press cake per cent cane has increased from 2.63 to 2.67 per cent. While the polarization is lower than in 1926, it is higher than in any previous year. The amount of press cake is higher than reported in any previous season. As the decrease in polarization is relatively greater than the increase in weight, the loss in press cake has been reduced. Calculated to per cent on cane, the reduction in this loss is moderate, but calculated as a percentage on polarization in cane the loss is but a trifle lower than the high mark reached last season.

The increased amount of press cake has increased the duty on filter press equipment to some extent. On the other hand lower juice densities have rendered it easier to obtain a lower polarization. On the whole the efficiency with which the filter presses have been operated does not seem to differ much from last season.

Additional filter press equipment has been installed at Lihue and Kohala and the Oliver Filter at Oahu was operated for the whole season as against a couple of months only in 1926. The loss in press cake per cent polarization in cane has been reduced approximately .1 at each of these factories.

Evaporation: Additional capacity has again been secured from evaporator equipment. Calculations on the same basis as those in the last few Synopses indicate an increase of 3.2 per cent in the amount of water evaporated per hour and .7 in the percentage of water evaporated on mixed juice. Although the equipment

has been operated at higher capacity, the Brix of the syrup has decreased, due to lower juice densities. This decrease from 64.04 to 63.10, brings the Brix of the syrup to the lowest point in six seasons.

Commercial Sugar: Commercial sugar polarization has increased from 97.30 to 97.40. Higher polarizations at factories shipping sugar to the Crockett refinery have brought about this increase. The average for other factories is slightly lower than last year.

Moisture in the sugar has been reduced from .68 to .65. The reduction in moisture is in slightly greater proportion than the increase in polarization, bringing the deterioration factor down to .250. This is the first time the deterioration factor has been reduced to this point.

Available data on refining qualities of the sugar are tabulated in the report of the Raw Sugar Technical Committee, to which reference is made for these data. We might note, however, that in size of grain the sugar has been poorer than in recent years both with respect to the proportion of the crop and the number of factories above the standard. The quality of the sugar has steadily decreased with respect to size of grain for several years. The filtration rate of sugar shipped to Crockett is somewhat lower than last year, 79.1 against 81.5. Increased grinding rates and lower purities have been factors contributing toward these undesirable changes in refining qualities.

Low Grades: Although higher grinding rates and lower juice purities have imposed additional duty on low grade equipment, the molasses purity has been reduced from 37.97 to 37.59. The tendency toward lower molasses purity can hardly be considered general, as 18 factories report higher against 19 reporting lower and 1 the same. While the average for this season is considerably lower than the 1926 average, lower figures have been reported in three previous seasons. The record made in 1925 is .27 lower than this year's average. After correcting for the change in analytical methods to put the figures on a comparable basis, 1919 and 1923 molasses purities are also lower than this season.

Notwithstanding more efficient low grade work, the influence of lower juice purities has been sufficient to increase the weight of molasses per cent cane from 2.93 to 3.03 and the loss of sucrose in molasses per cent cane from .99 to 1.02. With the additional factor of lower cane polarization, the loss of sucrose per cent polarization of cane has increased from 7.72 to 8.46. This is higher than in any previous year except 1921.

Kahuku has reported an average molasses purity of 31.81, thus establishing a new record. The previous record, 32.46 was made by the same factory in 1925.

Massecuite storage tanks have been replaced by crystallizers at Hamakua with a reduction of 4.59 in molasses purity in comparison with the previous season. A similar change was made at Hutchinson and although the new equipment was not in use the whole of the season an improvement of 1.44 was made in the season's average for molasses purity.

Undetermined Loss: Polarization averages in the large table indicate a reduction of .28 in undetermined loss while sucrose averages in Table 7 indicate a reduction of .07. The impression given by both of these figures is somewhat erroneous. In comparison with last season, the figure for undetermined loss based

on polarization has been depressed by the increase in the amount of molasses. This means that a larger proportion of sucrose (a relatively higher figure than polarization) has been subtracted from polarization in cane. We estimate that this factor has depressed the undetermined loss figure .13 in comparison with last year, basing this estimate on analysis of a large amount of polarization and sucrose data for molasses from practically all factories. Applying this correction, the reduction in undetermined loss based on polarization data becomes .15. On a sucrose basis the figures are influenced by data from Union Mill and Waianae. Union Mill reported .60 undetermined loss on a sucrose basis in 1926, but did not submit sucrose data in 1927. Sucrose data were not reported from Waianae last year, while this season an undetermined loss of 4.84 was reported on this basis. Data from these factories have influenced the sucrose average for undetermined loss to the extent of .04. This makes the corrected sucrose average .11 lower than last season, a figure in reasonably close agreement with the corrected figure of .15 on a polarization basis. With reference to the difference between these corrected figures, we would point out that a number of factories are not included in the sucrose averages. Also examination of polarization and sucrose data indicates that the ratio of polarization to sucrose in mixed juice is slightly lower than last year, while in the sugar this ratio remains unchanged. This factor contributes to the difference in question.

After correcting for the influence of different amounts of molasses, the undetermined loss this season is the lowest since these figures have been averaged.

Recovery

In comparison with last season boiling house recovery has decreased .37 and recovery per cent polarization of cane .36, bringing these figures to the lowest point since 1922. Higher sugar polarization has accounted for .04 of the decrease in recovery. As this does not influence the recovery of available sugar, on this basis we may consider that recovery has decreased .32 instead of the .36 noted above. The decrease in the quality of the juice corresponds to a considerably larger decrease in recovery than that actually sustained. Calculations on the basis of normal juice purity indicate that with the same quality of work as last season, the recovery would be depressed 1.09 instead of .32, thus indicating that when data are calculated to a comparable basis, an improvement over the work of last season corresponding to some .77 in recovery has been realized. Three factors account for the major part of this improvement. Larger increases in purity in clarification are equivalent to something in excess of .3 in recovery. Lower molasses purity is equivalent to between .15 and .2. Assuming that lower figures for undetermined loss reflect actual reductions in such losses rather than control errors, between .1 and .15 is accounted for in this way.

In summing up the season's work we find that the cane has been materially lower in quality. The chemical control has been improved through the inclusion of pH determinations and turbidity figures. There are also indications of improvement in the accuracy of the figures from year to year. Factories have been operated at higher capacity. There are indications that milling has been more

TABLE NO. 9

COMPARISON OF ACTUAL AND THEORETICAL RECOVERIES

		Recovery % Calculated Recovery *			Recovery % Recovery Indicated by "Sugar Ratio" †	
Rank	Factory	Milling	Boiling House	Over All	Rank	Over All
—	Kahuku	97.71	103.76	101.74	—	101.18
1	Hakalau	98.70	101.96	100.79	1	100.25
—	Waimanalo	98.06	102.38	100.73	—	100.53
—	Lihue	97.15	103.17	100.66	—	99.88
—	Onomea	98.53	101.68	100.44	—	100.50
—	Koloa	96.68	102.45	99.61	—	98.73
2	Ewa	98.18	101.03	99.51	3	99.61
3	Pepeekeo	97.63	101.73	99.49	4	99.29
4	Pioneer	97.52	101.29	99.33	6	98.76
5	Honomu	98.06	100.94	99.25	5	98.77
—	Haw. Sug.	97.34	101.54	99.04	—	99.68
6	Hilo	97.95	100.49	98.74	2	99.67
—	Oahu	97.45	100.92	98.70	—	99.27
7	Maui Agr.	97.17	100.72	98.36	8	98.01
8	Wailuku	98.27	99.53	98.09	7	98.38
9	H. C. & S. Co.	97.35	99.89	97.63	9	97.69
10	McBryde	96.79	100.14	97.27	10	97.45
11	Kilauea	96.68	99.71	96.96	17	95.97
12	Honokaa	95.72	100.74	96.92	19	95.82
13	Kekaha	98.21	98.21	96.90	11	96.74
—	Makee	95.67	100.72	96.78	—	94.96
14	Hamakua	97.16	98.80	96.43	16	96.02
15	Hawi	96.74	99.17	96.43	18	95.93
16	Waialua	97.41	98.48	96.23	12	96.65
17	Paauhau	97.42	98.19	96.05	13	96.61
18	Honolulu	96.92	97.18	95.50	14	96.18
19	Kohala	96.94	98.00	95.42	15	96.16
20	Olaa	96.73	98.27	95.39	20	95.48
21	Haw. Agr.	96.40	98.32	95.13	21	95.01
22	Laupahoehoe	97.04	96.45	93.86	22	94.40
23	Kaiwiki	96.15	97.03	93.56	23	93.66
24	Waimea	96.77	95.84	93.05	24	93.07
25	Waiakea	95.37	95.95	92.02	25	91.73
—	Union Mill	92.96	97.98	91.51	—	91.47
	Kaeleku	95.00	95.93	91.48	27	90.99
.	Halawa	92.65	97.97	91.20	26	91.56
28	Hutchinson	95.42	94.99	91.01	28	90.61
29	Olowalu	97.78	92.52	90.78	30	89.46
30	Niulii	93.70	96.29	90.63	29	89.55
31	Waianae	96.77	92.89	90.17	31	89.29

* Factories are arranged in the order of the ratio of their recovery to that calculated on the basis of 100% extraction, 37.5 gravity purity molasses and no other losses. Factories reporting boiling house recovery in excess of 101% on available (Table 4) are included in the table but no ranking is assigned.

† The basis of this calculation is 98.02 extraction, syrup purity one less than the apparent purity of the first expressed juice, gravity purity of molasses 33.33 and no other losses. In this case also no rank has been assigned when over 101% boiling house recovery on available has been reported.

efficient, though on account of the quality of cane there has been a slight decrease in extraction. The drop in purity from first expressed to mixed juice is slightly less satisfactory than last season. Much better results have been obtained in clarification and slightly better results at the filter presses. Better results have been secured also in the low grade work, notwithstanding the additional duty imposed on equipment by higher grinding rates and lower juice purities. Undetermined losses have been reduced. Control data, calculated to a comparable basis, indicate an improvement corresponding to between .7 and .8 in recovery as the net result of factory operation this season. Comparisons on the basis of quality ratio also indicate an improvement, though smaller than that indicated by control figures. On this basis, after correcting for the difference in sugar polarization, an improvement of .2 per cent is indicated.

Comparison of Actual and Calculated Recoveries

The usual comparisons of actual and calculated recoveries and a ranking of factories on this basis are in Table 9. Complying with suggestions that have been received, figures for all factories are given, but no ranking has been assigned to factories reporting in excess of 101 per cent of the theoretical boiling house recovery in Table 4, instead of omitting them from the table as in previous years. Comparisons on the basis of "sugar ratio," a calculation suggested by Mr. S. S. Peck, are also included in Table 9. Factors assumed in calculating "sugar ratio" are in a footnote under the table. It is identical with "cane ratio," recently adopted by the Association of Hawaiian Sugar Technologists in place of quality ratio, except that the actual instead of an assumed value is used for commercial sugar purity.

Relative standings as calculated by these two different methods are in fairly good agreement in most instances, though there are several rather large discrepancies. These are due principally to the difference in the values assumed for final molasses purity.

In previous Synopses we have expressed the opinion that calculations such as these are of value for giving a good general idea of the quality of the factory work, but that drawing close distinctions on such a basis is not justified. Discrepancies in the results given by these two calculations illustrate this point. Given accurate control data, we consider that a reasonably accurate estimate can be made as to how closely the actual recovery approximates the recovery it is possible to attain with present processes. Such an estimate, however, involves careful analysis of all control data. The various considerations involved are not readily expressed as a mathematical formula. Many formulae purporting to express the efficiency of factory operation as a percentage figure have been proposed. Some of these give a satisfactory approximate idea of the quality of the work, but all that have come to our attention are open to more or less serious objection from the standpoint of accurately defining the efficiency with which operations have been conducted.

Calculations in this Synopsis have been made by Mr. A. Brodie.

TABLE NO. 10

SUMMARY OF LOSSES

FACTORY	POUNDS POLARIZATION PER TON OF CANE						POLARIZATION PER 100 CANE						POLARIZATION PER 100 POLARIZATION OF CANE							
	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Bagasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Syrup Purity	FACTORY
H. C. & S. Co.	7.6	...	20.6	...	....	28.2	0.38	....	1.03	....	.....	1.41	2.65	0.01	7.14	....	—0.04	9.76	87.34	H. C. & S. Co.
Oahu	6.6	1.6	19.2	1.2	—2.4	26.2	0.33	0.08	0.96	0.06	—0.12	1.31	2.55	0.63	7.54	0.48	—0.99	10.21	85.53	Oahu
Ewa	4.6	1.0	19.4	...	1.2	26.2	0.23	0.05	0.97	....	0.06	1.31	1.82	0.42	7.70	....	0.47	10.41	84.20	Ewa
Waialua	6.8	1.2	18.2	...	4.8	31.0	0.34	0.06	0.91	....	0.24	1.55	2.59	0.46	6.97	....	1.82	11.84	86.2	Waialua
Maui Agr.	8.2	...	22.6	...	—1.4	29.4	0.41	....	1.13	....	—0.07	1.47	2.83	....	7.75	....	—0.51	10.07	86.18	Maui Agr.
Olaa	7.8	1.8	20.8	...	1.0	31.4	0.39	0.09	1.04	....	0.05	1.57	3.27	0.73	8.78	....	0.44	13.22	85.4	Olaa
Pioneer	6.8	0.8	20.8	...	0.2	28.6	0.34	0.04	1.04	....	0.01	1.43	2.48	0.28	7.64	....	0.10	10.50	84.61	Pioneer
Haw. Sug.	7.6	1.2	18.4	...	—3.4	23.8	0.38	0.06	0.92	....	—0.17	1.19	2.66	0.39	6.44	....	—1.22	8.27	87.39	Haw. Sug.
Lihue	6.4	1.4	18.0	...	....	25.8	0.32	0.07	0.90	....	.....	1.29	2.85	0.62	7.98	....	—0.01	11.44	81.8	Lihue
Onomea	3.2	0.4	17.2	...	0.2	21.0	0.16	0.02	0.86	....	0.01	1.05	1.47	0.15	7.85	....	0.07	9.54	84.27	Onomea
Honolulu	8.2	1.6	24.0	...	....	....	0.41	0.08	1.20	....	.....	....	3.08	0.58	9.05	....	.....	....	85.3	Honolulu
Hilo	4.6	0.6	16.8	...	0.2	22.2	0.23	0.03	0.84	....	0.01	1.11	2.05	0.32	7.47	....	0.06	9.90	85.59	Hilo
Kekaha	4.6	1.8	25.2	...	2.4	34.0	0.23	0.09	1.26	....	0.12	1.70	1.79	0.67	9.71	....	0.93	13.10	83.9	Kekaha
Haw. Agr.	8.0	1.0	21.2	...	1.4	31.6	0.40	0.05	1.06	....	0.07	1.58	3.60	0.41	9.41	....	0.65	14.07	84.61	Haw. Agr.
Hakalau	2.8	0.4	17.4	...	0.1	20.7	0.14	0.02	0.87	....	.....	1.03	1.30	0.14	7.75	....	0.04	9.23	83.68	Hakalau
Wailuku	4.6	1.0	22.2	0.2	0.4	28.4	0.23	0.05	1.11	0.01	0.02	1.42	1.73	0.39	8.24	0.09	0.13	10.58	85.4	Wailuku
Makee	9.2	1.2	21.4	...	0.2	32.0	0.46	0.06	1.07	....	0.01	1.60	4.33	0.57	10.11	....	0.10	15.11	81.8	Makee
Honokaa	8.4	1.0	19.2	...	0.2	28.8	0.42	0.05	0.96	....	0.01	1.44	4.28	0.46	9.69	....	0.10	14.53	82.21	Honokaa
McBryde	8.2	0.6	21.6	...	0.2	30.6	0.41	0.03	1.08	....	0.01	1.53	3.21	0.23	8.38	....	0.07	11.89	84.97	McBryde
Laupahoehoe	7.2	0.6	16.8	...	6.8	31.4	0.36	0.03	0.84	....	0.34	1.57	2.96	0.21	6.90	....	2.77	12.84	87.5	Laupahoehoe
Hamakua	7.2	...	19.2	...	2.0	28.4	0.36	...	0.96	....	0.10	1.42	2.84	....	7.66	....	0.81	11.31	86.52	Hamakua
Kahuku	4.8	1.2	16.8	...	1.0	23.8	0.24	0.06	0.84	....	0.05	1.19	2.29	0.54	7.86	....	0.49	11.18	81.26	Kahuku
Pepeekeo	5.2	0.6	16.8	...	0.4	23.0	0.26	0.03	0.84	....	0.02	1.15	2.37	0.27	7.57	....	0.13	10.34	84.1	Pepeekeo
Paauhau	5.4	1.0	21.2	...	1.6	29.2	0.27	0.05	1.06	....	0.08	1.46	2.58	0.48	10.02	....	0.71	13.79	83.69	Paauhau
Honomu	4.4	0.6	17.2	...	1.0	23.2	0.22	0.03	0.86	....	0.05	1.16	1.94	0.24	7.43	....	0.48	10.09	84.9	Honomu
Koloa	7.6	1.2	20.4	...	—1.0	28.2	0.38	0.06	1.02	....	—0.05	1.41	3.32	0.53	8.92	....	—0.43	12.34	82.3	Koloa
Waiakea	10.6	1.6	25.6	...	1.6	39.4	0.53	0.08	1.28	....	0.08	1.97	4.63	0.64	11.14	....	0.72	17.13	84.27	Waiakea
Hutchinson	10.0	0.6	23.2	...	5.4	39.2	0.50	0.03	1.16	....	0.27	1.96	4.58	0.23	10.66	....	2.48	17.95	84.36	Hutchinson
Hawi	7.8	1.4	25.0	...	0.2	34.4	0.39	0.07	1.25	....	0.01	1.72	3.26	0.56	10.45	....	0.12	14.39	82.57	Hawi
Kaiwiki	9.6	2.0	23.4	...	0.4	35.4	0.48	0.10	1.17	....	0.02	1.77	3.85	0.81	9.33	....	0.17	14.16	86.11	Kaiwiki
Kohala	7.4	2.2	21.8	...	0.1	31.5	0.37	0.11	1.09	....	.....	1.57	3.06	0.87	8.94	....	0.03	12.90	85.5	Kohala
Waianae	8.4	1.4	31.4	...	10.6	51.8	0.42	0.07	1.57	....	0.53	2.59	3.23	0.54	12.11	....	4.13	20.01	82.27	Waianae
Waimanalo	4.2	1.4	19.0	...	0.6	25.2	0.21	0.07	0.95	....	0.03	1.26	1.94	0.61	8.70	....	0.32	11.57	81.32	Waimanalo
Kilauea	6.8	1.8	25.8	...	1.8	36.2	0.34	0.09	1.29	....	0.09	1.81	3.32	0.85	12.55	....	0.88	17.60	78.9	Kilauea
Kaeleku	10.6	3.2	24.8	...	5.0	43.6	0.53	0.16	1.24	....	0.25	2.18	5.00	1.47	11.58	....	2.36	20.41	80.78	Kaeleku
Union Mill	15.4	2.2	19.2	...	1.0	37.8	0.77	0.11	0.96	....	0.05	1.89	7.04	1.02	8.72	....	0.44	17.22	84.5	Union Mill
Halawa	16.4	2.6	....	...	20.8	39.8	0.82	0.13	....	....	1.04	1.99	7.35	1.15	....	....	9.25	17.75	84.17	Halawa
Niulii	13.6	2.0	....	...	25.2	40.8	0.68	0.10	....	....	1.26	2.04	6.30	0.92	....	....	11.79	19.01	82.80	Niulii
Waimea	7.6	1.2	....	...	30.0	38.8	0.38	0.06	....	....	1.50	1.94	3.23	0.50	....	....	12.71	16.44	83.78	Waimea
Olowalu	5.8	0.6	22.0	...	21.0	49.4	0.29	0.03	1.10	....	1.05	2.47	2.22	0.23	8.29	....	7.91	18.65	83.29	Olowalu

Sugar Prices

96° Centrifugals for the Period December 17, 1927, to March 14, 1928

Date		Per Pound	Per Ton	Remarks
Dec.	17, 1927	4.65¢	$93.00	Cubas.
"	27	4.59	91.60	Cubas.
Jan.	4, 1928	4.63	92.60	Porto Ricos, 4.61, 4.65.
"	5	4.58	91.60	Philippines.
"	9	4.61	92.20	Cubas.
"	10	4.58	91.60	Porto Ricos.
"	13	4.52	90.40	Porto Ricos.
"	14	4.49	89.80	Cubas.
"	17	4.46	89.20	Cubas.
"	21	4.43	88.60	Porto Ricos.
"	24	4.415	88.30	Porto Ricos, 4.43; Cubas, 4.40.
"	27	4.40	88.00	Porto Ricos.
"	31	4.33	86.60	Cubas.
Feb.	1	4.27	85.40	Cubas.
"	2	4.24	84.80	Porto Ricos.
"	7	4.27	85.40	Porto Ricos.
"	8	4.24	84.80	Porto Ricos.
"	14	4.23	84.60	Porto Ricos.
"	15	4.21	84.20	Cubas.
"	18	4.14	82.80	Porto Ricos.
"	20	4.18	83.60	Porto Ricos.
"	23	4.225	84.50	Porto Ricos, 4.21, 4.24.
"	24	4.28	85.60	Porto Ricos, 4.24, 4.27; Cubas, 4.33.
"	27	4.27	85.40	Cubas.
"	28	4.365	87.30	Cubas, 4.33, 4.40.
"	29	4.40	88.00	Porto Ricos.
Mar.	7	4.36	87.20	Porto Ricos.
"	8	4.415	88.30	Philippines, 4.40; Cubas, 4.43.
"	9	4.445	88.90	Porto Ricos, 4.43; Cubas, 4.46.
"	10	4.46	89.20	Porto Ricos.
"	12	4.46	89.20	Porto Ricos.
"	13	4.505	90.10	Porto Ricos, 4.49; Cubas, 4.52.
"	14	4.52	90.40	Cubas.

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THE HAWAIIAN PLANTERS' RECORD

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Spraying Chlorotic Cane at Ewa Plantation Company

Spraying young ratoons affected with chlorosis with a 5 per cent solution of iron sulphate is proving very effective as is shown by the illustration on the cover.

This photograph was taken May 10, 1928, showing two plots of spraying experiment 1, 1929 crop, Field 9A (a coral area) Ewa Plantation Company. This experiment was previously harvested January 6, 1928, yielding an increase of 1.05 tons sugar per acre, resulting from one spraying when the young ratoons were three months old.

The present ratoons were sprayed twice, February 10 and March 16. The excellent condition of the sprayed plots, compared to the unsprayed plots, is the result of the cumulative effect from the previous crop and the early sprayings of the present ratoons.

The plantation replanted all plots irrespective of treatment to start this crop with an even stand, but the replants as well as the old stools in the bad chlorotic areas failed to develop normally.

The foreground of the photograph shows Plot 3X (not sprayed) and the background shows Plot 2S (sprayed).

Note that the sprayed plot has a good stand of cane, while the untreated plot in the foreground is a failure. This condition holds throughout the plots, though some spots are much better than others, due to difference in intensity of the factor producing chlorosis.

The effectiveness of the iron spray is dependent upon getting the spray early upon the very yellow young shoots, before they have depleted their original food supply in the old stool.

Spray at this critical stage saves the stand. After the ratoons have reached the age of 4 or 5 months, the chlorotic shoots have either died or recovered, so spraying may not appreciably affect the stand.

Parasitism of Fern Weevil, *Syagrius fulvitarsus* Pasc., at Kilauea, Hawaii

By C. E. Pemberton

From 280 *Sadleria* fern leaf-stalks, averaging two feet in length, collected at Kilauea, Hawaii, on March 2, 1928, by L. W. Bryan, and shipped to Honolulu, the following information was obtained regarding the present status of the fern weevil at Kilauea, in relation to its introduced parasite:

Number of weevil adults emerging	162
Number of parasites *Ischiogonus syagrii* emerging	174
Average weevil infestation per stalk	1.2
Percentage of parasitism	30.5

The above figure of parasitism is based on the assumption that an average of 2.5 parasites develop on one weevil larva. From 1 to 4 parasites usually mature on a single grub. The total of 174 parasitic wasps which emerged from the stems from March 4 to March 26, thus represents approximately 69.6 weevil larvae killed. This plus the 162 unparasitized weevils which also emerged, gives a total weevil infestation in the 280 stems of 231.6.

Thirty per cent is not a particularly high percentage of parasitism, but such is usually the case in nature's balance when the pest is suppressed by its parasites to a low point. While studying this weevil and its parasite in ferns in New South Wales in 1921, the weevil was always comparatively scarce, yet the parasitism of its larvae by *Ischiogonus* during April and May of that year was found to average only about 10 per cent. With any increase in weevils, there follows a rapid rise in degree of parasitism until the pest is once more decimated by its parasite and both remain scarce for a time, with an accompanying lower degree of parasitism.

That the parasitic control of the weevil at Kilauea by *Ischiogonus syagrii* is now very satisfactory, is indicated by the average number of weevil infestations of the fern stems. Only slightly over one weevil or grub per stem occurred, as compared with pre-parasite days when most of the stems in the weevil-infested area each contained a large number of grubs with consequent dying off of much of the stems.

The 174 *Ischiogonus,* which emerged from the stems from Kilauea, were liberated locally where fern weevils were known to be present.

Preliminary Report on a Pot Study Using "Molashcake"

By R. E. Doty

Early in November, 1927, it was arranged to start a molashcake pot test.

The object of this experiment was to determine the response of H 109 cane to this comparatively new mixture of bagasse, mill ash, molasses and filter cake, known as molashcake. There were 24 concrete tubs used in this test. These tubs were 2 feet by 2 feet by 2 feet inside measurement, having a capacity of 8 cubic feet of soil.

The soil used in this experiment was obtained from the Manoa substation.

Mr. Stewart, chemist, reporting on the soil analysis states: "This soil is decidedly acid and has a low content of available phosphate. There is a good supply of available potash in this soil, but a rather low content of total reserve potash and phosphates."

MANOA PLOTS (AGRICULTURAL DEPARTMENT)
Calculated to Water Free Soil
Composite Sample of 64 Pots

		1% Citric Acid Soluble				Strong HCl Soluble			Total by Fusion		
Lab. No.	Soil Reaction pH	Silica SiO_2	Lime CaO	Potash K_2O	Phosphoric Acid P_2O_5	Lime CaO	Potash K_2O	Phosphoric Acid P_2O_5	Potash K_2O	Phosphoric Acid P_2O_5	Nitrogen N
		%	%	%	%	%	%	%	%	%	%
3763	5.3	0.10	0.49	0.062	0.0033	0.94	0.11	0.14	0.36	0.26	0.28

The molashcake used was composed by weight as follows:

Mudpress cake	33.8%
Bagasse	12.2
Mill ash	5.5
Molasses	48.5
	100.0%

One-eye cuttings of H 109 cane were used as the planting material. These cuttings were started in small cutting boxes on December 20, 1927. Only uniform shoots were actually planted to the tubs on January 26, 1928. Owing to the shortage of large sized tubs, there were only two repetitions of each treatment.

The treatments are given in detail herewith:

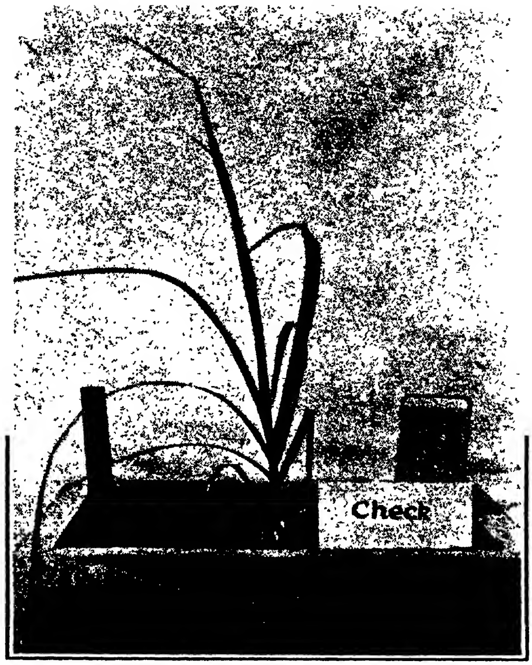


Fig. 1—Check—no treatment.

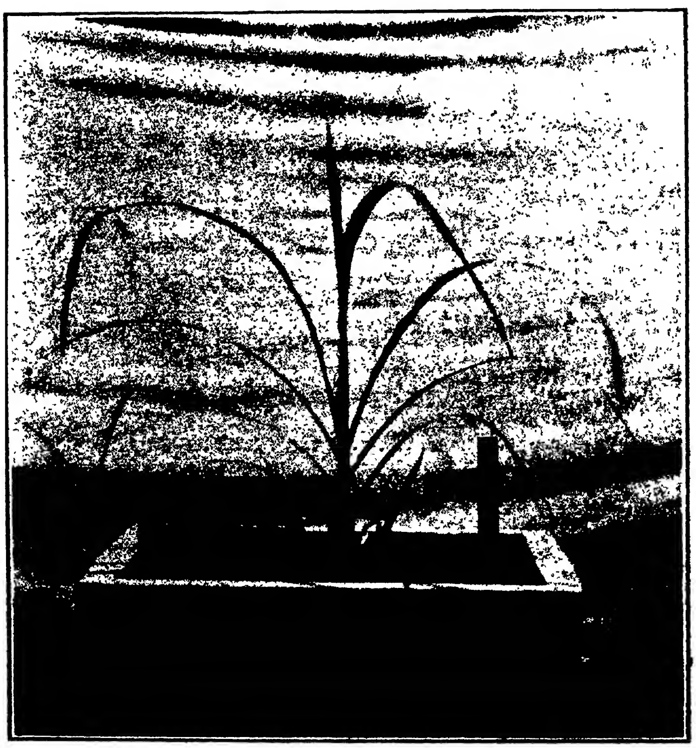


Fig. 2.—Check—with complete fertilizer added one month after planting.
Note the slight increase in growth over Fig. 1.

Treatments applied to soil two months before planting time:

1. Check—no treatment.
2. Molashcake—20 T. P. A. applied two months before planting.
3. Molashcake—20 T. P. A. applied two months before planting + complete fertilizer applied at regular time (one month after planting).
4. Molashcake—20 T. P. A. + complete fertilizer, both applied together two months before planting.
5. Molashcake—40 T. P. A. applied two months before planting.

Treatments applied at planting time or later:

1. Check—no treatment.
2. Molashcake—20 tons per acre.
3. Molashcake—20 tons per acre + complete fertilizer applied one month after planting.
4. Complete fertilizer only—applied one month after planting.
5. Molashcake—5 tons per acre and planted immediately.
6. Molashcake—5 tons per acre applied to growing crop one month after planting.
7. Molashcake—5 tons per acre + complete fertilizer, both applied one month after planting.

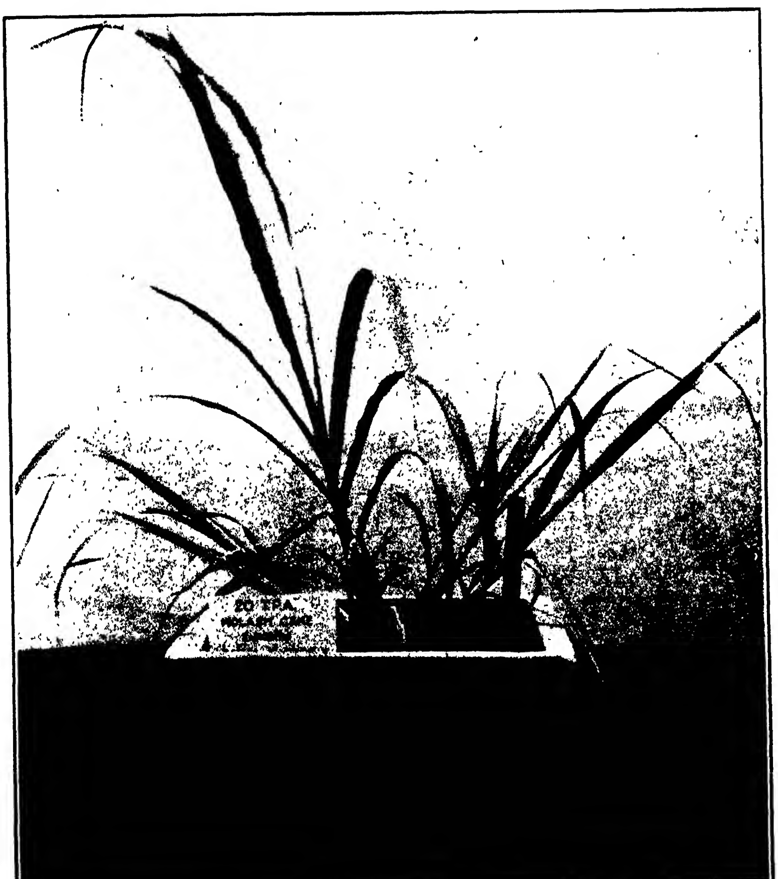


Fig. 3.—Molashcake applied at the rate of 20 T. P. A. two months before planting. Note the excellent stooling.

Observations were made and photographs were taken April 25, or at the age of three months from the planting of the germinated eyes to the tubs. The molashcake applied at the rate of 20 tons per acre two months before planting has given the cane a great stimulus. The use of a complete fertilizer in addition to the molashcake has given some added but less pronounced growth.

The application of 40 tons of molashcake gave even better results in fine growth and stooling.

The checks, both those without any treatment and those with complete fertilizer alone, gave decidedly less response.

A good idea of the status of the various treatments can be had from the accompanying illustrations.

This experiment will be followed through as long as the cane can grow in this size of pot. The entomologists will examine the soil and roots to determine, if possible, whether the different treatments had any effect on the nematode population.

Fig. 4.—Molashcake applied at the rate of 20 T. P. A. two months before planting, plus complete fertilizer one month after planting. Compare with Fig. 3.

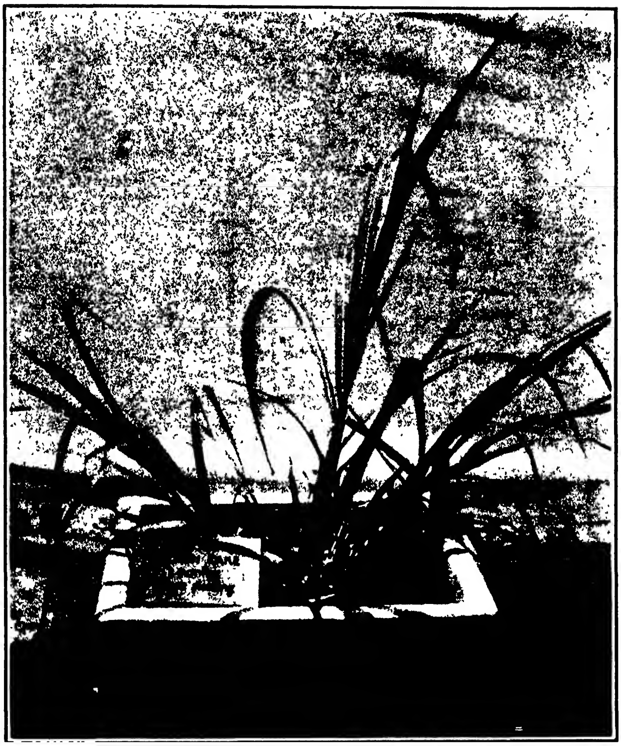


Fig. 5.—Molashcake applied at the rate of 40 T. P. A. two months before planting.

Monthly Plantings of H 109 in Relation to Eye Spot

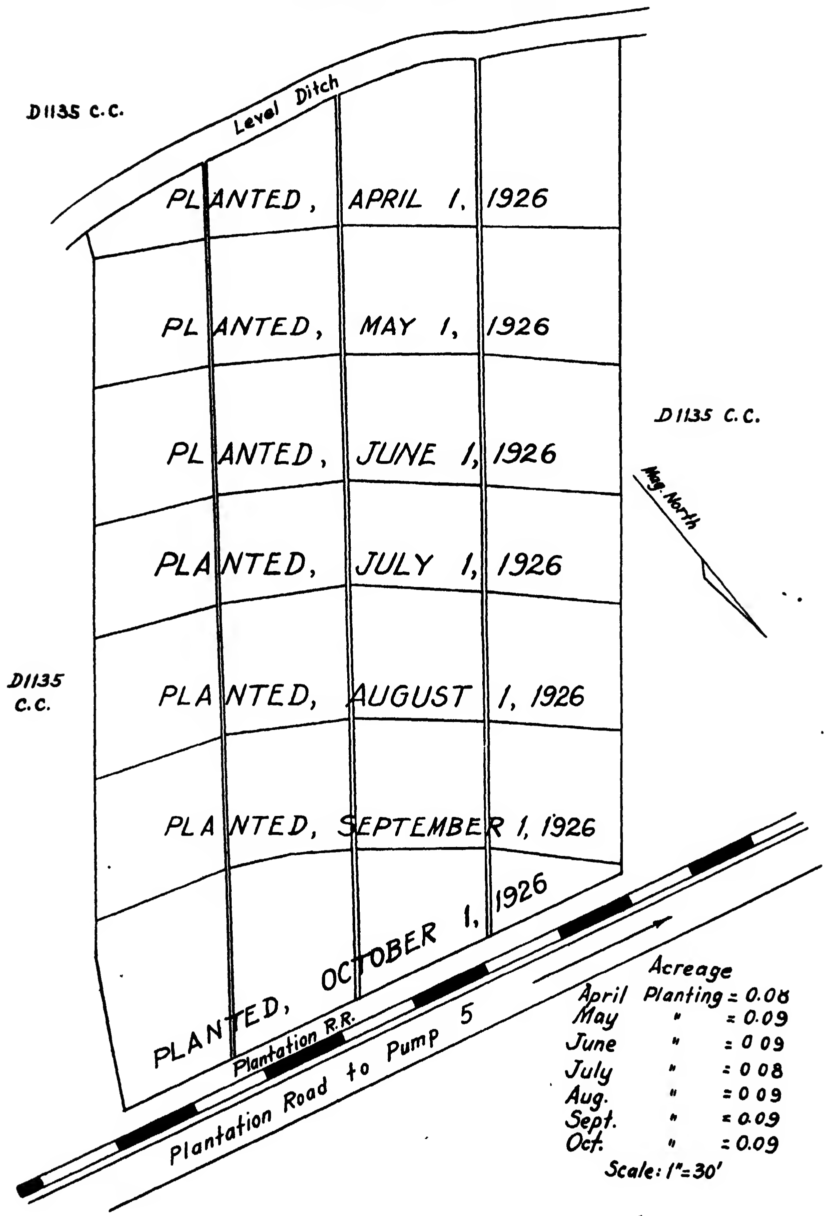
By J. P. Martin

From numerous field observations it was recognized that late-planted or -harvested cane located in eye spot areas was always much more affected with the eye spot disease as compared to early-planted or -harvested cane.

Since the time of year cane is planted has such a direct bearing on the eye spot problem it occurred to the writer to make monthly plantings of H 109 cane in an eye spot locality and note carefully the degree of infection on each planting during the eye spot season. Such an experiment was planned for more or less of an observation test and approximately twenty-four lines, or six lines in four watercourses each of H 109 cane, were planted in Field Kawaihapai 1A of the Waialua Agricultural Company, Ltd., the first of April, May, June, July, August, September and October, 1926. For details of this experiment please refer to the map accompanying this article.

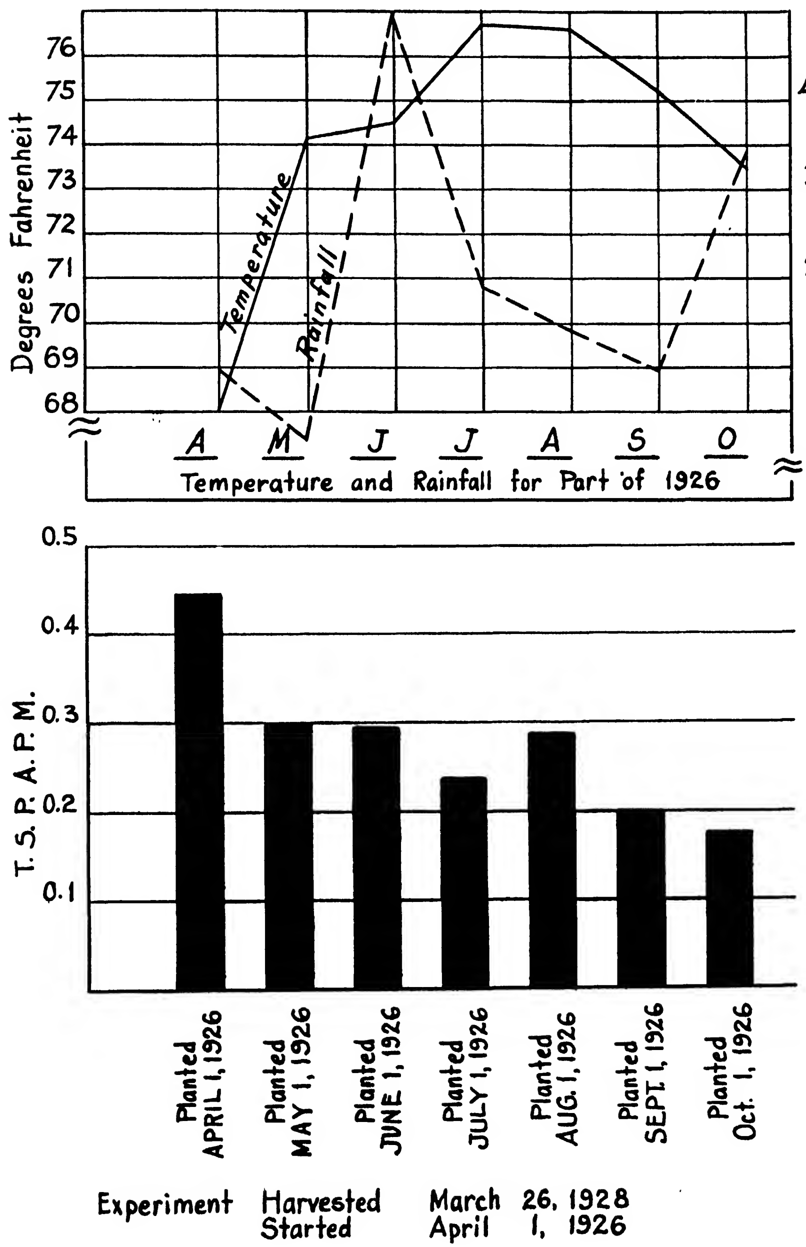
MONTHLY PLANTINGS OF H109 CANE IN RELATION TO EYE SPOT

Field Kawaihapai 1A, W. A. Co., Ltd.



Eye spot was very severe during the season of 1926 and 1927 and the degree of infection on the different plantings was extremely striking at the peak of the eye spot season. The cane that was planted the first of April, May, and June, especially April and May, made splendid growth during the summer months and only a small amount of leaf infection occurred during the winter months. The

T. S. P. A. P. M. FROM MONTHLY PLANTINGS OF H109 CANE



damage resulting from eye spot on these plots was almost negligible. There was a marked decrease in cane growth on the July and August plantings as compared to the earlier plantings with a distinct visible increase of leaf infection and top rot. It was evident that considerable damage had taken place in the July and August plantings from the heavy infection.

The cane that was planted in September and October made very little growth up to November, 1926, which was the beginning of the eye spot season. During the winter months much of this cane was killed outright, and top rot was extremely common; it seemed that only a very small amount of the cane would survive the severe attack of the disease.

Each planting received fertilizer at the rate of 100 pounds of nitrogen (from nitrate of soda), 70 pounds of K_2O, and 70 pounds of P_2O_5 per acre. In May, 1927, all plots received 500 pounds of mixed fertilizer (50 per cent nitrate of soda and 50 per cent ammonia sulphate). The late fertilization aided greatly in increasing the severity of the disease in the later plantings, but this condition is often similar to plantation practice.

During the eye spot season of 1927 and 1928 the cane in this experiment was of good size and very little infection occurred. The cane surrounding this experimental area was D 1135 and no heavy sources of infection were sufficiently near to influence the results one way or the other.

The observation results of this planting test were so outstanding in relation to eye spot that it was decided to harvest the experiment. On March 26, 1928, this experiment was harvested and the results obtained are presented in the table.

All juices in the various plots were uniformly low at this time of the year and this one fact accounts largely for the low sugar yields. There was a wide variation in the number of tons of cane per acre from each plot. We would expect to have a difference in cane tonnage due to the monthly plantings, but we would not expect such a large difference had not eye spot entered into the problem. The April planting bordered a level ditch and this explains the exceptionally heavy tonnage. With the exception of July and August there is a definite decrease in the tons-sugar-per-acre-per-month produced from each plot from April to October, and is illustrated in the chart as well as the temperature and rainfall for the months of 1926 when the various plantings were made. The harvesting results of this experiment are as outstanding as the observations were at the peak of the eye spot season in February, 1927, regarding the degree of infection on each planting.

The above results are not entirely conclusive because of having only one repetition of each planting, but they aid greatly in confirming our present knowledge in that the older the cane is as it enters the eye spot season the more resistance it has to the disease. Therefore, all susceptible varieties when planted in eye spot localities should be planted and harvested as early as possible. To prevent having any young cane entering the eye spot season a plan has been developed by the writer regarding the harvesting of eye spot fields. In brief, the plan is to segregate all the eye spot fields from the non-eye spot fields and place the eye spot fields under a two-year cropping system. This system will be presented in another paper entitled, "The Control of Eye Spot by Two-Year Cropping."

HARVESTING RESULTS OF MONTHLY PLANTINGS OF H 109 CANE IN RELATION TO EYE SPOT

Experiment Started April 1, 1926 — Experiment Harvested March 26, 1928

Date Planted	Acreage	Age of Cane in Months at Harvest	Brix	Pol.	Pur.	T. C.	T. C. P. A.	T. S. P. A.	Q. R.	T. S. P. A. P. M.
April 1, 1926....	0.08	24	14.6	11.52	78.9	10.80	135.00	10.655	12.67	.444
May 1, 1926......	0.09	23	14.1	11.01	78.1	8.22	91.333	6.826	13.38	.297
June 1, 1926.....	0.09	22	14.9	11.67	78.3	7.30	81.167	6.447	12.59	.293
July 1, 1926......	0.08	21	15.0	11.77	78.5	4.91	61.437	4.931	12.46	.235
August 1, 1926....	0.09	20	15.9	12.71	79.9	5.79	64.333	5.663	11.36	.283
Sept. 1, 1926.....	0.09	19	13.0	9.36	72.0	5.73	63.666	3.741	17.02	.197
October 1, 1926...	0.09	18	13.9	10.24	73.7	4.24	47.11	3.101	15.19	.172

Preliminary Report of a Tub Experiment Using "Molashcake" and Iron Pyrite on Chlorotic Areas

By R. E. Doty

The object of this study was to determine the response of H 109 chlorotic seed to treatments of "molashcake"* and pyrite (synthetic) when planted in a chlorotic area in which ratoon cane had previously died out.

There were seven treatments of four tubs each. These tubs measured 18 inches diameter at the surface of the soil or an area of 1.76 square feet. The soil used in this experiment was obtained from a bad chlorotic area at Ewa Plantation Company, in which all cane had died. To a depth of seven inches this soil appeared to be an excellent red loam, but from 7 to 14 inches there was a layer of almost pure coral sand and some rock. Below 14 inches it was almost solid rock.

The surface soil and subsoil were bagged separately and hauled to the Makiki Plots.

In filling the tubs care was taken to fill the bottom with subsoil and place a layer of surface soil on top to the same depth (seven inches) as it occurred in the field. This is called a normal "chlorotic soil" in this report.

The seed was obtained from very chlorotic areas at Ewa, where the yellowing of the cane persisted throughout the crop. This seed material proved to be a poor germinator. Some replanting had to be done to secure a satisfactory stand.

The following treatments were tried:

Set 1—Normal chlorotic soil only.
Set 2—Normal chlorotic soil + 20 tons molashcake per acre.
Set 3—Normal chlorotic soil + 40 tons molashcake per acre.
Set 4—Normal chlorotic soil + 60 tons molashcake per acre.
Set 5—All surface red soil + 20 tons molashcake per acre.
Set 6—All coral subsoil + 60 tons molashcake per acre.
Set 7—Normal chlorotic soil + 20 tons molashcake per acre + iron pyrite.

This experiment was planted November 1, 1927. Necessary fertilization was uniform for all tubs.

The photographs, taken May 15, 1928, accompanying this report (Figs. 1-5) give a good idea of the condition of this experiment at the age of 6½ months.

The normal layer of red soil at the surface seemed to keep the cane from a serious case of chlorosis (see Fig. 1) though the growth is below normal. The addition of 20, 40 and 60 tons of molashcake stimulated growth to a marked degree.

* This term is being applied to bagasse, molasses, furnace ash, and filter press cake mixed with bagasse.

Note particularly the growth of cane in the coral subsoil plus 60 tons of molashcake. That cane is not able to subsist on this coral subsoil unaided, is illustrated in Figs. 6 and 7 from another pot experiment. This study was carried out at the same time with the same soil. The only difference being the type of pot which gave slightly more depth of subsoil.

The canes in Fig. 6 are growing in subsoil only, without treatment. Note that one plant is dead, one is dying, and one is in bad condition (very yellow). The fourth plant is only fair. Compare these conditions with Fig. 7, in which iron pyrite only was added to the surface of the soil and allowed to oxidize and convert slowly to iron sulphate. The cane has an excellent green color and is growing well, though not as fast as the cane receiving molashcake.

This is a demonstration that iron pyrite scattered in the soil can cure chlorosis. At present prices, however, iron pyrite is not economical in field practice. Further work is being done on the use of pyrite.

Fig. 1. Normal chlorotic soil.
Note—Surface red soil prevents a serious case of chlorosis. Compare with subsoil (see Fig. 6).

Fig. 2. Chlorotic soil plus 20 tons of molashcake per acre.

Fig. 3. Chlorotic soil plus 40 tons of molashcake per acre.

Fig. 4. Chlorotic soil plus 60 tons of molashcake per acre.

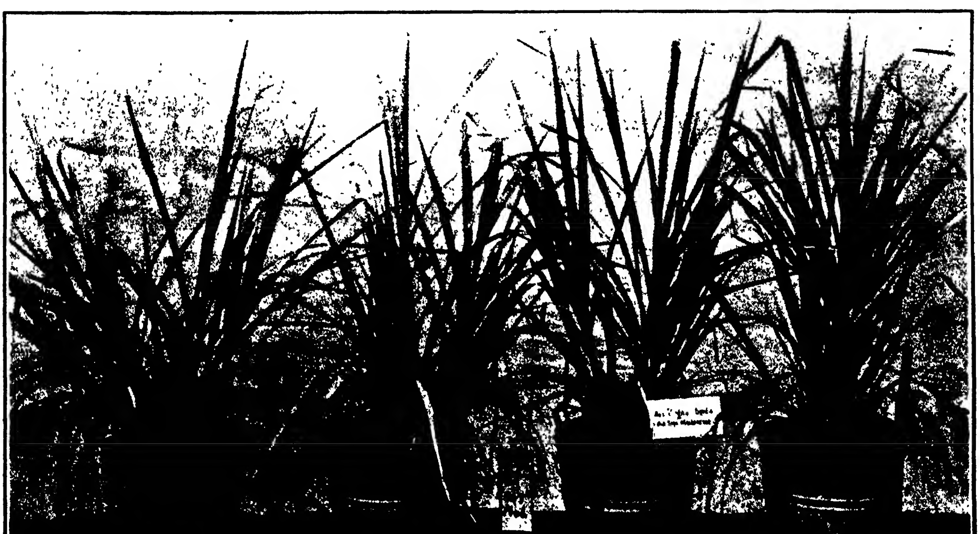


Fig. 5. All coral subsoil plus 60 tons of molashcake. Compare with Fig. 6, which is coral subsoil untreated.

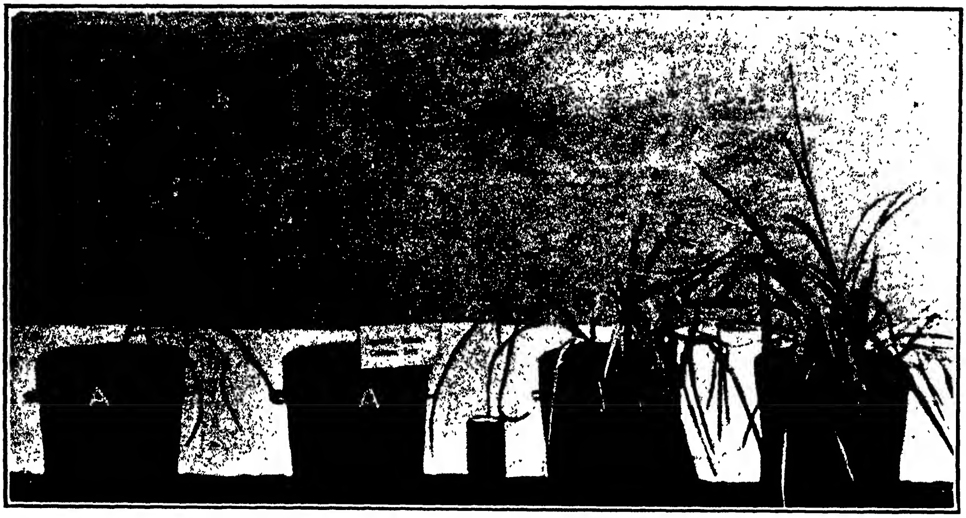


Fig. 6. All coral subsoil untreated. Rather liberal fertilization failed to affect the cane.

Fig. 7. All coral subsoil plus iron pyrite (iron disulphide) added to surface of soil. Compare with Fig. 6—untreated.

Field Observations on the Degree of Resistance and Susceptibility of Seedlings to Eye Spot

By J. P. Martin

The economic control of eye spot will be effected through the selection of a commercial cane resistant to the disease. Within the last four years a great deal of research has been conducted on seedlings in relation to eye spot. The writer has spent the past four eye spot seasons at the Waialua Agricultural Company, Ltd., studying the disease from all angles but concentrating on resistant varieties. A great deal of credit for the development of this latter phase of the problem is due to H. K. Stender, of the agricultural department of the Experiment Station.

At the present writing over 400 seedlings are under observation in eye spot localities at Waialua. A large number of these seedlings are highly resistant to the disease, but their commercial possibilities are not definitely established. Checkerboard experiments of the outstanding resistant canes are now well under way to determine their commercial value. Each seedling is planted in four or five repetitions with H 109 check plots adjoining each variety being tested. All plots are from 12 to 20 lines in size. This is the last time these canes will be tried and only those approaching or excelling H 109 in sugar production will be spread.

In order to carefully record all field observation notes in relation to eye spot, agricultural qualities and mosaic disease, a system was developed by the writer, October, 1926, which may be briefly explained as follows:

E. S. R. (Eye Spot Resistance)
- ++, Very much more resistant than H 109.
- +, More resistant than H 109.
- =, Susceptibility equal to H 109.
- —, More susceptible than H 109.
- — —, Very much more susceptible than H 109.

A. Q. (Agricultural Qualities)
- ++, Very superior to H 109.
- +, Superior to H 109.
- =, Equal to H 109.
- —, Inferior to H 109.
- — —, Very inferior to H 109.

M. D. (Mosaic Disease)
- B. A., Badly affected.
- S. A., Slightly affected.
- —, No mosaic disease present.

In this system H 109 is used as the standard throughout and all comparisons are made with it. In planting any seedling test H 109 is always planted next to each seedling. An example illustrating the use of this system is herewith presented:

FIELD KAWAIHAPAI 1-A, MAP NO. 523, PLANTED JULY, 1926. W. A. CO., LTD.

Seedling Under Observation	Date of Observations								
	Nov. 1, 1926			Dec. 2, 1926			Jan. 2, 1927		
	E. S. R.	A. Q.	M. D.	E. S. R.	A. Q.	M. D.	E. S. R.	A. Q.	M. D.
P. O. J. 36....	++	=	—	++	=	—	++	=	—
Ewa 621.......	+	—	—	+	—	S. A.	+	—	S. A.
H 8139........	+	—	—	=	—	S. A.	=	—	S. A.

In the above example P. O. J. 36 was very resistant to eye spot throughout the season. Ewa 621 was more resistant than H 109. H 8139 was more resistant than H 109 on November 1, 1926, but on December 2, 1926, and January 2, 1927, it was equal to H 109 in its susceptibility to the disease. With this system it is possible to notice any change of susceptibility of a seedling if observation notes are taken periodically during the eye spot season. The agricultural qualities of all seedlings can be closely watched and it is possible to determine when any seedling falls behind or excels H 109. The presence of mosaic disease can easily be recorded and it may be determined if the disease is increasing or decreasing.

In some instances it was found necessary to grade a seedling with =+ for E. S. R., or A. Q., which would indicate that it was just between an = and a + for eye spot resistance or agricultural qualities. An =— is also used at times indicating that the seedling is between an = and a — for E. S. R. or A. Q.

At the close of the eye spot season only those seedlings with a + for E. S. R. and an = for A. Q. are given a further trial. Those that are given a further trial are again planted in an eye spot area to confirm our previous knowledge of their resistance to the disease.

The object of this paper is to present a complete list of all seedlings being tested, with notes on the field observations of the many seedlings regarding their eye spot resistance or susceptibility according to the method as outlined above. In many cases a number of observations were made on the same seedling and the symbol representing its E. S. R. or A. Q. in the following table is the average of all observations. It will be noticed that the E. S. R. of a few seedlings is not listed; either these varieties have not passed through an eye spot season or there was not sufficient eye spot present in the particular locality where these seedlings were being tested to determine their resistance or susceptibility to the disease.

NOTES ON SEEDLINGS NOW UNDER OBSERVATION IN RELATION TO EYE SPOT AT THE WAIALUA AGRICULTURAL COMPANY, LTD., MAY, 1928

Seedling	A. Q.	E. S. R.	Seedling	A. Q.	E. S. R.	Seedling	A. Q.	E. S. R.
Wailuku 1	—	*	P. O. J. 979	=—	++	Waialua 43	=	+
" 2	=+	=+	" 2221	—		" 44	=	++
" 4	—	=	" 2379	—		" 45	=—	+
" 5	=—	+	" 2714	=		" 46	=—	+
" 11	=—	+	" 2725	—		" 47	=	+
" 12	=—	++	" 2727	—		" 48	=—	=
" 13	=—	=+	" 36M	—		" 49	=—	+
Striped Mex.	—	+	B. H. 10–12	—		" 50	=	+
Waipio 7	=	+	D. I. 52	—		" 51	—	++
" 8	=	+	S. W. 3	—		" 52	—	++
20-S-16	=—	+	Waialua 1	=—	++	" 53	=	+
H 5909	=—	++	" 2	—	+	" 54	=	=
H 5919	=	++	" 3	——	++	" 55	=—	=
H 5923	=—		" 4	=	+	" 56	=—	=
H 5946	—	+	" 5	—	—	" 57	—	+
H 5965	—	++	" 6	—	++	" 58	=	+
H 5986	+=	=	" 7	—	—	" 59	=—	+
H 8136	=	=	" 8	=	+	" 60	—	+
H 8139	—	=	" 9	=—	++	" 61	—	+
H 8158	—	+	" 10	—	+	" 62	=—	+
H 81360	=—	+	" 11	—	+	" 63	—	=
H 86143	—	+	" 12	=	—	" 64	—	+
H 86441	=	=	" 13	=—	+	" 65	=—	+
H 86465	—	+	" 14	—	++	" 66	=+	=+
H 86472	—	++	" 15	=—	+	" 67	=—	+
H 86484	=	++	" 16	=	++	" 68	=—	+
H 8942	=—	++	" 17	=—	++	" 69	=—	—
H 8952	=	++	" 18	=—	+	" 70	=+	+
H 8954	=	+	" 19	=—	=+	" 71	=+	+
H 8961	=—	++	" 20	=—	+	" 72	=—	++
H 8965	=—	+	" 21	=	+	" 73	—	+
H 8988	=	+	" 22	=—	+	" 74	—	+
H 8993	=—	+	" 23	—	+	" 75	=—	+
H 8994	=—	++	" 24	=—	=	" 76	=	+
H 89102	=	+	" 25	=—	+	" 77	—	=
H 89291	—	+	" 26	=—	=+	" 78	—	+
H 89296	—	=	" 27	=+	+	" 79	=—	+
H 89321	—	++	" 28	—	++	" 80	=—	+
H 9806	=—	+	" 29	=—	+	" 81	—	+
H 9809	—	+	" 30	=—	+	" 82	—	+
H 9811	=—	+	" 31	=	++	" 83	=—	—
H 9812	=—	++	" 32	=	+	" 84	=—	+
H 9909	—		" 33	=	+	" 85	—	=+
H 9910	—	+	" 34	=—	+	" 86	=—	+
H 9913	—		" 35	=+	+	" 87	—	+
H 9923	—	+	" 36	=	++	" 88	=—	=
H 9924	—		" 37	=—	+	" 89	—	+
P. O. J. 36	=—	++	" 38	=—	+	" 90	—	+
" 213	—	++	" 39	—	=+	" 91	=—	+
" 228	—		" 40	=—	+	" 92	=	+
" 234	—	++	" 41	—	+	" 93	=—	+
" 826	—		" 42	=—	+	" 94	=—	+

* Where no rating is given for the E. S. R., sufficient data were lacking to establish the degree of resistance to the disease.

Seedling	A. Q.	E. S. R.	Seedling	A. Q.	E. S. R.	Seedling	A. Q.	E. S. R.
Waialua 95	—	+	25–C– 5	=	=	1924 UD 39	=—	++
“ 96	—	+	“ 6	—	+	“ 42	=—	++
“ 97	—	+	“ 7	—	+	“ 58	=—	+
“ 98	—	+	“ 8	—	+	“ 62	—	+
“ 99	—	+	“ 9	—	=—	“ 66	=—	++
“ 100	=—	+	“ 10	—	=	“ 75	=—	++
“ 101	—	+	“ 11	=	+	“ 79	—	++
“ 102	—	+	“ 12	—	+	“ 88	—	++
“ 103	=—	=	“ 13	—	=	“ 92	=—	++
“ 104	=	=+	“ 14	—	+	“ 100	=—	++
“ 105	=—	+	“ 15	—	+	“ 104	=—	++
“ 106	—	+	“ 16	—	+	“ 106	—	++
“ 107	=	+	“ 17	—	—	“ 110	=—	+
“ 108	=—	+	“ 18	—	=	Ewa 199	—	——
“ 110	=	+	“ 19	=	=—	“ 325	=	+
“ 111	—	+	“ 20	—	=	“ 371	=—	+
“ 112	=	+	“ 21	=—	+	“ 533	=	++
“ 113	—	+	“ 22	—	+	“ 555	=	+
“ 114	—	+	“ 24	—	+	“ 569	+	++
“ 115	=	+	“ 25	—	+	“ 570	+	++
“ 116	=	+	“ 26	—	=	“ 607	=+	=+
“ 117	—	=	“ 27	—	—	“ 608	=+	+
“ 118	=—	+	“ 28	=—	=+	“ 609	——	+
“ 119	=—	+	“ 29	—	=	“ 610	—	=+
“ 120	=	+	“ 30	—	+	“ 611	=	++
“ 121	—	+	“ 31	—	++	“ 612	—	=+
“ 122	=—	+	“ 32	=	+	“ 613	—	=+
“ 123	=—	+	“ 33	—	=	“ 614	—	=+
“ 124	—	+	“ 34	=—	+	“ 615	=—	=
“ 125	=—	+	“ 35	=	=+	“ 616	—	++
“ 126	=	+	“ 36	—	=	“ 617	—	=
“ 127	—	+	“ 37	—	++	“ 618	—	+
“ 128	=—	+	“ 38	—	+	“ 619	—	+
“ 129	—	+	“ 39	——	+	“ 620	—	++
“ 130	=—	+	“ 40	=—	—	“ 621	—	+
“ 131	=	+	“ 41	—	++	“ 622	=—	=—
“ 132	=	+	“ 42	—	=+	“ 623	=—	—
Kohala 73	=—	+	“ 43	—	=	“ 624	—	—
“ 107	=—	+	“ 44	—	=	“ 625	=	=
“ 115	—	+	“ 46	=—	+	“ 626	+	=+
“ 117	—	=	“ 47	—	+	“ 627	+	=
“ 202	=—	+	U. H. 1	=—	++	“ 628	=	+
Manoa 160	=—	+	“ 2	=—	++	“ 629	=—	—
“ 198	=	++	“ 3	=—	++	“ 630	=	—
“ 300	=—	+	25–Q– 1	—	+	“ 631	—	—
“ 302	—	++	“ 11	=—	=	“ 800	=	=
“ 303	—	++	“ 18	=	+	“ 801	——	+
“ 304	=—	++	“ 70	—	+	“ 802	—	=—
“ 305	=—	++	“ 73	=—	+	“ 803	—	—
Makaweli 1	—		“ 79	=—	=+	“ 804	—	+
“ 3	—	++	“ 110	=—	+	Paia 150	=+	+
McBryde 1	—	—	“ 119	=—	+	“ 180	=	+
“ 3	—	=+	“ 126	—	——	“ 186	=—	+
“ 4	=—	+	“ 156	—	+	“ F	=	+
“ 5	=—	=	“ 159	=—	=	Nalo 13	=—	+
25–C– 1	—	+	“ 214	—	+	“ 31	—	=+
“ 2	=	+	“ 224	—	=	“ 44	—	+
“ 3	—	+	1924 UD 1	=—	+	H 47102	=—	
“ 4	=—	+	“ 23	—	+	Kekaha 456	—	=+

The A. Q. of each variety is listed, but will differ to a great extent according to the locality in which it is growing; therefore the A. Q. of each seedling should be established according to the location where it is being tested. The E. S. R. of a few of the above seedlings may vary somewhat on other plantations, depending on the severity of the disease in the particular area where the canes are being tested.

Notes on Pythium Root Rot

III

By C. W. Carpenter

In the last two numbers of the *Planters' Record* notes on current investigations of root rot of cane being carried on by the Department of Pathology were presented. This paper discusses theoretical considerations for research into the nature of certain factors associated with *Pythium* and Lahaina failure, considering this a specific, widespread disease distinct from localized growth failures. Following this discussion are condensed notes on a fourth inspection of the experimental plots of Lahaina planted on the island of Hawaii.

Pythium and Possible Associated Factors

It is evident that there are some undetermined factors associated with *Pythium aphanidermatum* in its attack on cane in the various localities and soil types, which as in the past exert a controlling influence on the root disease. These soil factors appear to be closely related to nutrients, leaching and drainage.

In an attempt to develop a suitable working theory for our research into the nature of these controlling factors, another review of our available records was made. A selected group of the more significant observations on Lahaina disease, recorded in the past thirty years, was kept in mind, while the records were searched, first with one tentative hypothesis in consideration, then another. Finally noting an apparent correlation of the occurrence of disease with the history of fertilization as well as records of rainfall, a theory of excess or unbalanced nutrients was entertained as possibly applicable throughout the diverse conditions where the disease occurred, and of these nutrients the interrelations of the nitrogeneous group were considered to be the most likely field for first attention. The present auxiliary theory to the *Pythium* concept is based on the suspected relation of nitrate nutrition to susceptibility.

As a part of the working theory we reason that as varieties differ in various ways including sugar production, they may differ in nutritional requirements, in quality and particularly in amounts. Are the requirements of Lahaina and other root rot susceptibles for nitrates relatively low? Are nutrients absorbed by this susceptible group beyond amounts needed, and does this excess induce suscepti-

bility to *Pythium* and other root rot organisms? Since varietal resistance appears to be only relative, susceptibility must be acquired under some conditions by our resistant types. Does the presence of excess available nitrogen at times lead to susceptibility in our resistant varieties when we reach amounts beyond those the plant can efficiently use? Very little attention appears to have been given to the question of the effect of excess of nutrients in relation to root failure and to susceptibility to attack by root organisms. Considering plant diseases in general, it is the well-nourished or over-nourished plant that is preferred by parasites, in contrast to the usual belief that the plant must be subjected to adverse conditions.

Since writing a preliminary note in a recent monthly report on suspected differences in nutritional requirements as a variety characteristic, a paper by Arrhenius* has come to my attention in which he points out that P. O. J. 2878 differs from E. K. 28 in nitrogen requirements, the latter being able to use less. With respect to amount of nitrate assimilated E. K. 28 has minimum requirements; P. O. J. 2878 has medium ability to absorb nitrates. Since our H 109 apparently is able to make better use of nitrogen in large amounts than some other varieties, it would appear that ability to use nitrate is a varietal quality, as Arrhenius suspects. This writer also states that cane absorbs a great deal more nitrogen from rich soils than from poor ones, apparently more than is required for immediate needs.

A discussion of the reasons for selecting for study the possible influence of excess nitrogen or unbalanced nutrients in bringing on root failure or susceptibility to attack by *Pythium* and other root organisms may be of interest. The series of observations selected from our records which were thought to be of great significance if correctly interpreted as a whole are stated below, with comments:

1. The widespread occurrence of the Lahaina failure on our diverse soil types and at various elevations with a diversity of weather and moisture conditions; irrigated land as well as unirrigated.

The widespread occurrence of the disease necessitates a widespread causal condition. *Pythium aphanidermatum* appears to be of similar wide occurrence and experimental evidence has demonstrated an active relation to root rot. Since there are records of recoveries, which cannot be satisfactorily explained otherwise, we must assume that certain factors exert a controlling influence on the disease, factors which are similarly of wide occurrence and effective under such diverse soil and climatic conditions as we have, for example, at Olaa, Onomea, Ewa, Oahu and Honolulu plantations, at elevations of 15 to 1250 feet.

2. At Onomea (1897 and later). Occurrence of the disease in the richer hollows, the poorer lands not being so badly affected. (John T. Moir, in Proceedings, H. S. P. A. 1913, p. 43.)

The relation of the richer soils and rich hollows to nutrition is self-evident. They would be likely to first show any effects of an oversupply of nutrients by direct application and moderate leaching to lower levels.

* Arrhenius, Dr. O. Mededeelingen van het Proefstation voor de Java-Suikerindustrie. No. 3, 1928.

3. At Ewa and Oahu Plantations first appearance at edge of fields, near ditches, roads, etc., spreading thence. The disease following the rows, borders of diseased patches often sharply defined by a furrow or shallow ditch. According to the late George F. Renton, the disease was much worse in dry periods, dry summers after dry winters, etc.

We have to imagine the relation of ditches, roads, etc., to possible excess of nutrients in the near-by fields. Were these spots low and poorly drained? If so the soluble plant foods may have accumulated there from higher portions of the field by leaching and drainage. Such places may have been used as distribution centers for fertilizers. Owing to location or by accident they may have received too much.

The aggravated condition in dry seasons is possibly due to several inter-related factors: Conservation of water and the lesser ability of the reduced root systems of root rot plants to absorb available irrigation water; concentration of soluble nutrients in less soil water; reduced leaching, if any; increased nitrification in hot, dry weather, and resulting accumulations, especially if the same amount of fertilizer was added as in an ordinary wet year.

4. Record of a field of Lahaina on Maui, where it was mentioned, incidentally, that before the failure of the cane, portions of the field were used for storage of piles of manure from the stables. Before this the field always yielded well. (Field 16, Hawaiian Commercial and Sugar Company.)

The possible relation to excess nutrients is suggestive.

5. Remarkable crop recoveries of Lahaina-diseased fields, the only significant constant precedent condition being unusual rainfall. Normal canes developed on the stunted, short-jointed sticks. Some improvement has been noted as following unusually heavy irrigations.

Unusual rainfall would leach out or tend to equalize uneven distribution of soluble material of the soil.

6. The growth of Lahaina in 80 per cent virgin soil and 20 per cent sick Waipio soil in a tub test was about as good as the growth in virgin soil. (Experiment by H. P. Agee.)

As an explanation of this point, since the organisms of the sick soil would be presumed to be transplanted with the sick soil, there would be dilution of the associated factor, which we suspect was an excess of nutrients.

7. Remarkable recovery of sick stools removed with adhering soil to the Pathology Plot at Alexander Street. Normal canes developed on the stunted sticks, and then three good ratoons were obtained. (Experiment by H. L. Lyon.)

The possibly significant point in relation to the theory of excess nutrients in the recovery of plants by removal to the Pathology Plot is that the soil of the new location *had never been fertilized* and the transplanted cane *was not fertilized.* The soil was not virgin to cane.

8. Failure of Lahaina, seed from three sources, on virgin land at Waipio. (Experiment by H. P. Agee.)

The failures of Lahaina on virgin soil were a surprise to those making the test. It was considered significant in relation to our theory of excess nutrients that the location of the experiment had recently been cleared of a growth of algaroba and was probably high in nitrogen as well as in organic matter, and low in potash and phosphoric acid. We do not know whether or not it was fertilized. The outcome of the experiment points to nitrogen as in some way involved. Since the algaroba is a leguminous plant we would expect more nitrogenous content of this soil than in the usual virgin soil. Fertilizers, if applied, might have resulted in excess of this nutrient, already abundant, or lack of balance of nutrients.

Considering the relation of dry weather and unusually dry seasons to the disease as pointed out by Mr. Renton, the following is quoted from Russell,* indicating a possible seasonal increase in our soil nitrates:

In a dry summer the nitrate formed is all left in the soil or taken up by the crop; in a wet summer some of it is washed out. This is shown by comparing the amounts of nitrate present on an unmanured fallow plot at Rothamsted during the wet summer and autumn of 1912 with those present in the dry summer of 1913. In the top 18 inches of soil amounts were found equivalent to the following quantities of nitrate of soda, in pounds per acre, showing a very great difference in favor of a dry summer:

	February	May	September
Dry Summer			
1913	126	312	376
Wet Summer			
1912	180	138	114
Difference in favor of dry summer, reckoned in pounds nitrate soda per acre		174	262

At Ewa Plantation Company, where, according to above statement, Lahaina disease was always worst in dry summers following dry winters, we can visualize a similar accumulation under irrigation plus added fertilizers, all soluble soil elements tending to concentrate in the soil moisture present. Nitrification too would be at a maximum.

On unirrigated plantations, with cropping we would expect similarly an accumulation of nitrates, if the same amount of fertilizer was applied as for a wetter season, there being less leaching loss and the amount present being in solution in a smaller quantity of soil moisture. Organic matter is known to be present in rather large amounts in the soils of many of our unirrigated plantations; with consequent large amounts of potential nitrogenous nutrients and with nitrification again more active or the accumulations larger in dry seasons we might have a condition of excess nitrogen.

The variety E. K. 28 failed from root rot at the Pathology Plot in a field high in organic matter which as far as we know had never been fertilized previously; it was fertilized with ammonium sulphate. The outside row grew much better than the rest of the plot, which we believe was due to the fact that its roots had access to undisturbed soil on one side. Lahaina has generally grown well in this location, but it was never fertilized.

* Russell, E. J. A Student's Book on Soils and Manures. 1919.

We know something of the relation of nitrogen to the susceptibility of cane to eye spot disease. It has been pointed out by Lee* that under suitable weather conditions a supply of available nitrate in the soil favors susceptibility to eye spot (*Helminthosporium sacchari*). It seems reasonable to conjecture that the roots of Lahaina and other root rot susceptibles, in the presence of excess nitrate, certain types of nitrogenous nutrients, or suddenly increased amounts of the same, might be similarly rendered highly susceptible to the attacks of root organisms.

According to the literature there is a general belief that nitrogen in excess leads to succulent growth and that phosphates and potash have an ability to counteract in a measure the tendencies of nitrogen to stimulate such growth. Regarding the effect of excess of nitrogen, Russell† tersely summarizes the general belief perhaps as clearly as anyone. He writes as follows:

> Applied in excess it tends to thin cell walls, making them more readily penetrated by fungoid pests, and it also appears to affect the composition of the sap in some way so that the fungi develop more readily than usual.

It is thought that the highly soluble nitrates and nitrogenous elements of the soil which most writers consider as being readily lost by leaching if not quickly used by the crop, would under moderate moisture conditions tend rather to accumulate in low places, flats, etc., by leaching (lateral drainage). There would tend to be a greater concentration near places where nitrates were unloaded and dissolved in the irrigation water, and near ditches, roads, etc., which serve as bars to lateral seepage. Rich hollows, as well as the edges of fields in the vicinity of roads, etc., would likely be first to show the effects. Any places receiving more nitrate by accident or design than usual would be likely to first have an excess. The observed bad field conditions in the presence of coral and in inoculation tests in the presence of coral sand is thought to be a result of increased nitrification.

Since the symptoms of Lahaina failure or root rot simulate nitrogen starvation, is it not a fact that many such spots were touched up with more nitrate as the natural first step in seeking better growth? Apparently so, for all through the literature of this Lahaina trouble we find the statement "it did not respond to fertilization."

The older analyses of good and poor Lahaina soils often show more nitrates in the "poor soils" than in the "good" locations,‡ but this fact is not emphasized, since both showed a sufficiency. There are analyses showing the reverse, it is true, but since we are not sure of time of sampling, or location of sampling with reference particularly to fertilizer applications, rainfall, and drainage, in relation to onset of the diseased condition, the data may not be applicable. Whether nitrogen is absorbed and is present in greater amounts in "sick" cane than in healthy remains to be learned.

* Lee, H. Atherton. Eye Spot Disease. Report of the Association of Hawaiian Sugar Technologists, 1926. pages 46-47.

† Loc. cit., p. 129.

‡ Burgess, P. S. Soil Investigations Pertaining to the Lahaina Disease. *Hawaiian Planters' Record*, Vol. XIV, 1916. p. 366.

In the history of fertilization we find a suggestion of correlation of applications of nitrogenous manures with Lahaina failure. In a broad way only, we can trace an apparent correlation in time of general tendencies of fertilization practice with the major outbreaks of the disease. More exact is the correlation of outbreaks with exceptionally dry periods, a coincidence first emphasized at Ewa Plantation by Mr. Renton.

Our first authentic outbreak of Lahaina disease on a large scale began at Onomea plantation in 1897. As to fertilization tendencies in general we interpret the conditions as follows: Prior to 1895, when this Station was started and definite fertilization policies based on soil analyses were recommended, fertilization was practiced, phosphates predominating; nitrogen was but 2-3 per cent of the formula; the idea apparently being to use fairly complete fertilizers when possible, and little was known as to definite requirements of our soils.

After the soils had been studied by Dr. Maxwell (1895-1896), the possible loss of nitrates by leaching was brought out and this type of nutrient was noted as the one essential nutrient likely to be, or to become, deficient, and a limiting factor. Thus nitrogen application was emphasized. Correlated at Onomea then with a possibly greater use of nitrogenous fertilizer than formerly we have the exceptionally dry weather of 1897. This was the driest year in the Hilo district in 24 years of record. No record has been found for Papaikou (Onomea plantation) for that year. At Pepeekeo, 100 feet elevation, rainfall was also low, being 85.96 inches, a record low for 29 years (the mean was 131.56 inches). We may then speculate on the possible correlation of Lahaina failure at Onomea in 1897 in relation to abnormally dry weather as well as possible excess of nitrates in the richest hollows, through greater application as well as through increased nitrification. Lahaina failure in this case was correlated in time with dry weather and a changing tendency in fertilization.

At Olaa, the failure of Lahaina is correlated in 1906 with unusually low rainfall for the district. In 1906, at Waiakea the rainfall was 99.59 inches, the mean for 27 years being 136.10 inches (elevation 50 feet); at Olaa Mill, rainfall was 117.08 inches, low for 12 years, the mean for 18 years being 152.92 inches (elevation 250 feet). What relation this lower rainfall had to Lahaina failure we do not know, since if well distributed it would appear to have been sufficient; there would be less leaching, and on these soils, high in organic matter combined with fertilization practice, disturbance in nutrient balance may have resulted through nitrification. Decreased rainfall appears less significant than content of organic matter in normally or excessively wet regions, high in organic matter.

In 1910, the Eckart formula of fertilization was advocated, carrying a higher proportion of nitrogen. This came into general use. The year 1912 was a record dry year and Lahaina failure came into prominence at Ewa, Oahu, and Honolulu plantations. The poor condition of Lahaina had been noted at Ewa and Oahu plantations about 1905; and subsequently it reached a climax in 1911-1912, dry years, Lahaina being soon almost entirely replaced by resistant varieties. Ewa had pioneered for some years with a high nitrogen formula in advance of the Eckart formula of 1910.

The annual rainfall at Ewa, Waipahu and Puuloa in significant years with relation to Lahaina disease may be tabulated, as of great interest, in relation to outbreaks of the disease.

ANNUAL RAINFALL (FROM TABLES OF U. S. WEATHER BUREAU)

Year	Ewa 50 Feet	Waipahu 200 Feet	Puuloa 15 Feet
1900	15.39		
1901	29.56	26.10	
1902	25.41	22.55	13.06
1903	13.40	9.30	15.68
1904	44.14	49.55	50.73
1905	**7.19**	**10.74**	**9.36**
1906	22.67	20.45	21.10
1907	29.24	28.78	23.56
1908	14.09	18.42	14.74
1909	17.59	14.20	16.14
1910	15.16	16.65	18.45
1911	16.57	20.43	17.64
1912	**8.20**	**12.62**	**8.42**
1913	**15.82**	23.54	**15.55**
1914	16.64	20.39	19.06
1915	20.40	28.24	20.31
1916	35.23	44.40	33.35
1917	36.32	44.46	39.21
1918	35.83	39.09	33.49
1919	**8.55**	**10.55**	....
1920	24.24	42.30	....
1921	19.78	29.07	....
1922	8.56	20.39	....
1923	26.49	....	....
1924	21.12	....	....
1925	9.77	12.96	....

As above discussed the general history of fertilization supports the theory that the factors associated with *Pythium* attack on Lahaina cane roots are related to fertilization and that the dry weather prevailing in the years of major outbreaks was instrumental in allowing a greater function of the factor. *Pythium aphanidermatum,* with the way prepared appears the most generally active agent in root destruction. Other root attacking organisms may be similarly encouraged by the same factors, high nitrogen, low potash and phosphoric acid.

Nitrate-Phosphoric Acid-Potash Ratio:—The literature indicates that excessive nitrogen induces susceptibility to leaf diseases, but that available potash and phosphoric acid in relation to total nitrates have considerable modifying influence. Stewart* has found that on the upper lands of the Oahu Sugar Company a deficiency of phosphoric acid was associated with root disease of H 109 cane.

Naquin† has suggested the relation of deficiency of potash to a form of root rot at Honokaa plantation, the symptoms being similar. He writes as follows:

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* Stewart, G. R. Report on Soils and Fertilizers. *Hawaiian Planters' Record,* Vol. XXIX, 1925. p. 260.

† Naquin, W. F. Proceedings of H. S. P. A. 1925. pp. 43-45.

Recently a case of acute potash deficiency occurred in a kuleana where cane was planted for the first time four years ago. This was D 1135, and the symptoms were noticed about six months after the cane had been cut, when the young cane was growing vigorously and there was an excessive amount of cane per linear foot. Gradually the symptoms developed and spread, so that the whole area was affected in different degrees of acuteness.

Field tests were started three months ago, when applications were made of nitrate, 200 lbs. active ingredients per acre, potash 400 lbs. and phosphate 400 lbs. per acre.

The cane where potash was applied immediately picked up and started a new growth; cane which had reached the size of a lead pencil, and had only a few leaves, immediately increased the number of leaves and gained in girth. Three months after the application of potash all of the plants were growing normally.

In cases where nitrate and phosphate were applied the conditions were more or less aggravated; most of the cane died out and a secondary crop of suckers is coming out at present.

Miles and Thomas* write as follows in the summary of their work on the relationship between manuring and susceptibility of potatoes to the virus diseases (leaf curl and mosaic), *Rhizoctonia solani, Colletotrichum tabificum* and *Phytophthora infestans* (blight):

1. The excessive use of nitrogenous manures favors the incidence of disease in the potato crop.
2. The quantity of nitrogenous manure may be regarded as excessive only when not balanced by adequate amounts of potash.
3. The capacity of disease resistance in plants varies directly with the quantity of potash supplied in the fertilizer.
4. For the promotion of healthy plant growth sylvinite and the lower grades of potash salts are less efficient than muriate and sulphate of potash.
5. Probably owing to manurial practice in the past, the application of phosphates to potato crops on the silt soils of the Holland division of Lincolnshire tends to increase the susceptibility to disease.
6. Heavy dressings of a well balanced compound manure tend to increase the immunity of the crop to disease.

Conclusions numbered 2 and 3 of Miles and Thomas on the relation of potash and nitrogenous manures to plant disease appear significant in the light of Naquin's observations given above and our records of available soil potash contributed by Stewart†. For example, potash was found generally low at Olaa plantation and may be deficient in such soils in relation to available nitrogen, so that we have increased susceptibility to *Pythium aphanidermatum*.

From our preliminary experiments there is thus far no conclusive evidence that excess nitrogen is directly related to susceptibility of cane to root rot. It would appear a very simple matter to demonstrate in a short time the truth or fallacy of the reasoning. Since, however, even in virgin lands the disease did not generally show up for one or two years, and the exact procedure to follow to duplicate field conditions is unknown, a great deal of research may be necessary to demonstrate the truth of the matter. Should the factor be in reality a disturbed relation of the nitrogen-phosphoric acid-potash ratio, rather than a mere excess of nitrate, the problem becomes greatly complicated.

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* Miles, Herbert W., and Thomas, Brynmor. A preliminary study of the relationship between manuring and susceptibility to disease in potatoes. In *Journal of Agricultural Science*, Vol. XV. 1925. pp. 89-95.

† Stewart, G. R. In Directors' Annual Report, Experiment Station, H. S. P. A. 1926. Proceedings of Annual Meeting. p. 266.

The possibilities of exact demonstration by experiments with cuttings in small soil cultures are curtailed by the influence of the mother "seed" piece. If from a healthy source, apparently the whole must be changed in composition by the new environment before the roots become susceptible; if from a "sick" plant, the reverse appears true; the roots are already susceptible in some degree and similar modifications set in, if grown in a good soil. More soil is needed apparently than is provided by the small units now in use, or experimentation changed to lalas rather than "seed."

Any exact information on the relation of nutrition to susceptibility to root rot of cane is desirable not only with respect to the failure of Lahaina, E. K. 28 and other highly susceptible varieties, but particularly in its bearing on the sporadic outbreaks of root rot in commercial varieties. Root rot of various crops apparently may arise from a variety of causes, yet there appear to be certain characteristics of a great many such root rots which suggest that a fundamental disturbance in growth is a precedent condition. This disturbance paves the way for various root rot organisms.

Notes on Root Rot on the Island of Hawaii

A fourth inspection of the experimental Lahaina plots planted in May, 1927, by the Olaa Sugar Company, Ltd., the Honokaa Sugar Company, the Onomea Sugar Company, and the Pepeekeo Sugar Company, in cooperation with the Experiment Station was made April 23-27, 1928.

There has been no noteworthy change from the description of the general features of the several plots as recorded in the April, 1928, *Planters' Record.* The plot in Field J-2 at Olaa was the most striking failure of the series, with the mauka plot in Field 33 at Onomea Sugar Company, a close second. In the plot in Field J-2 very little advance in growth could be noted since the January inspection. A number of stools had small, short-jointed canes, while other stools were about dead. Growth was nearly at a standstill and had been very slow since August. A few upstanding leaves, very pale green to yellow or bleached out, and rather dry, at the ends of the sticks were characteristic. The whole plot was in most decided contrast with the adjoining Yellow Caledonia, both in size and color. The plot in Field 33, at Onomea, was not in much better condition except for a minority of the stools which in color and size appeared more healthy. The general color here was better.

The mauka plot, in Field W at Olaa, was in better condition than the one makai. There was better color and through the middle of the area a definite strip of larger and nearly normal plants extended diagonally across the rows of the plot. Outside of this strip, stunted plants were the rule, though conditions appeared more nearly normal than in the makai plot.

At Onomea, in Field 34, we found still present the interesting condition previously discussed in our notes.* This area crosses a small hollow, the portion near the road and the back also being somewhat higher than the middle. The cane on the higher ground was fine with little contrast in size or general appearance with the Yellow Caledonia adjoining. It appeared normal, though tonnage might be

low. The cane in the middle portion, though growing fairly well, was much smaller, continuing the conditions noted in previous reports. This plot continues as an excellent illustration of Mr. Moir's earlier statements that the disease was worse in the hollows and in the richer soils. It would appear that the good and bad portions of this plot offer an excellent opportunity for a critical search for differences.

The plot at Pepeekeo continued to show great unevenness in size of stools. Some might be considered nearly normal but the majority were stunted, though of fair color. The cane tops had not closed in yet to smother weed growth. It may be said that this plot was in a middle position in our series, not as good growth as that in Onomea, Field 34, being more irregular, and not by any means as bad as that in Olaa, Field J-2. This cane is at the lowest elevation of any of our plots.

At Honokaa, in Field 29, we found a continuation of good growth as described in the January inspection report. Though rather uneven, as nearly as we could judge in the heavy growth, the canes were large, with long joints and probably represent nearly normal growth for the variety in that location. This cane compared favorably with the better areas of the plot in Field 34, Onomea; the plots in Onomea, Field 34, Honokaa, Field 29, and Pepeekeo, Field 1, having the best growth of Lahaina in our series.

Portions of the mauka plot at Honokaa, in Field 6, continued a fair growth, possibly better than fair considering elevation, and the growth of near-by standard canes. There was, however, a large percentage of more or less stunted and weak stools. By comparison we placed this plot in a class with the mauka plot at Olaa, Field W, and the mauka plot at Onomea, in Field 33.

Grouping the plots as to general appearance and size we have the three plots with portions of nearly normal growth: Onomea, Field 34; Honokaa, Field 29, and Pepeekeo, Field 1, all makai plots; of poor or moderate growth, Honokaa, Field 6; Olaa, Field W, and Onomea, Field 33. In a class by itself is the plot in Field J-2 at Olaa; this plot has from the start shown most serious signs of distress and is the only one that remains almost unchanged month after month.

The fungus *Pythium* was observed in the roots of stools from all plots except in Field 29, at Honokaa. It has been found here previously. There was a considerable development of new white roots. Little evidence of *Pythium* root rot was found.

The *Pythium* type of root rot and the fungus were present in the roots in all the other plots. In general the lesions were not as conspicuous as in previous inspections, though there were few roots and much rotting of new as well as old roots in most of the root systems examined. Three additional pure cultures of *Pythium* type were isolated, one from Honokaa, Field 6, one from Onomea, Field 33, and one from Onomea, Field 34. Again the presence of a rough-walled oospore, apparently of a species of *Pythium* or *Aphanomyces* was commonly noted. Attempts to culture this in Hilo with field equipment have failed. In general this fungus appears to be associated with *Pythium aphanidermatum* and it may be only a secondary invader.

Paper Mulching For Sugar Cane

By J. A. Verret

During the 1927 and 1928 seasons, eleven paper mulching experiments were harvested. Seven of these were planned and laid out by the Station, two were conducted by Olaa Sugar Company and two by the Oahu Sugar Co. These tests all contained a good number of repetitions of each treatment and we consider the data obtained reliable. The experiments were under both irrigated and unirrigated conditions and were on three different islands.

The paper used in all these tests, except those at Olaa, was Pabco No. 224, 18 inches wide, perforated with a V cut. Olaa paper was used at Olaa.

The paper was placed between the cane rows and the cane was moderately hilled. The bottoms of the furrows were leveled so that the paper laid flat and not trough-shaped.

In the Olaa tests the paper was laid over the cane lines and not between them.

In the following table we give the location of the experiments, varieties of cane, age, plant or ratoon:

TABLE I

No. and Location	Variety of Cane	Kind	Age	Remarks
Olaa Sugar Co. Field G............	Y. C.	1st rat.	18 mos.	Not irrigated
Olaa Sugar Co. Field 101...........	Y. C.	7th rat.	18 mos.	Not irrigated
Wailuku Sugar Co. Exp. 17.........	H 109	4th rat.	19½ mos.	Irrigated
Waimanalo Sugar Co. Exp. 9........	H 109	3rd rat.	19½ mos.	Irrigated
Waipio, Section 27.................	H 109	5th rat.	16 mos.	Irrigated
Paauhau Sugar Pl. Co. Exp. 22....	H 109	3rd rat.	20 mos.	Irrigated
Paauhau Sugar Pl. Co. Exp. 23......	D 1135	4th rat.	23 mos.	Not irrigated
Pioneer Mill Co. Exp. 65...........	H 109	2nd rat.	22 mos.	Irrigated
Pioneer Mill Co. Exp. 66...........	H 109	2nd rat.	22 mos.	Irrigated
Oahu Sugar Co. Field 3B...........	H 109	....	....	Irrigated
Oahu Sugar Co. Field 32A..........	H 109	....	....	Irrigated

The results of the harvests are summarized in Table II:

TABLE II

Exp. No	No. of Plots per Treatment	T. C. P. A. Paper	T. C. P. A. No Paper	Q. R. Paper	Q. R. No Paper	T. S. P. A. Paper	T. S. P. A. No Paper
Olaa Sugar Co. Field G.....	..	39.1	33.5	8.59	9.04	4.55	3.70
Olaa Sugar Co. Field 101....	..	55.7	61.1	8.67	8.54	6.42	7.15
Wailuku Sugar Co. Exp. 17..	4	47.9	50.2	7.65	7.60	6.27	6.56
Waimanalo Sugar Co. Exp. 9.	12	59.0	56.8	9.25	9.30	6.38	6.10
Waipio, Sec. 27	11	51.5	52.3	8.02	8.03	6.42	6.42
Paauhau Sugar Pl. Co. Exp. 22	8	55.5	55.8	11.34	12.53	4.89	4.45
Paauhau Sugar Pl. Co. Exp. 23	11	69.1	67.8	8.65	8.51	7.99	7.97
Pioneer Mill Co. Exp. 65....	8	44.3	42.4	7.16	7.19	6.19	5.90
Pioneer Mill Co. Exp. 66....	8	71.7	71.2	7.36	7.39	9.74	9.63
Oahu Sugar Co. Field 3B....	..	91.5	87.7	8.48	8.48	10.79	10.34
Oahu Sugar Co. Field 32A...	..	63.4	60.0	9.72	9.35	6.52	6.40
Average.............		59.0	58.1	8.63	8.72	6.92	6.78

These results show that with our present system of agriculture, paper mulching between the cane rows does not pay. There may be some exceptions to this when exceptional conditions are met. In wet fields, for instance, which are too rocky to allow of implement cultivation, weed control by hand may be so expensive as to suggest the use of paper. But we understand that it has been found better in such cases to put the paper directly over the cane line, and not between the cane lines, and to use poison spray on the area not covered by the paper.

Under irrigated conditions where weed control is not a serious problem we do not believe that paper has anything to offer. We do not believe that the possible saving in water due to decreased evaporation from the papered areas can be great enough to pay for the paper.

The cost of papering will be at least $30.00 an acre. Even with the most expensive water it would require not less than a saving of a million gallons or 37 acre-inches to pay the cost. Eighteen-inch paper in five-foot lines covers less than one-third of the surface area.

With our present system of rapid forcing, the young cane closes in rapidly. After the cane closes in and shades the ground we do not believe that the paper will have much effect on evaporation or temperature.

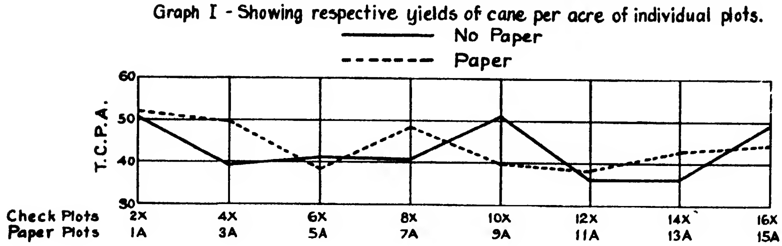
This leaves only a short time in which the paper can be of most effective use. We believe this to be largely responsible for the fact that paper has not shown up better than it has with sugar cane, especially under irrigated conditions.

We have detailed notes and individual plot yields of these experiments on file. These data are available to any one desiring to make a detailed study of these results.

Paper Mulch Experiment

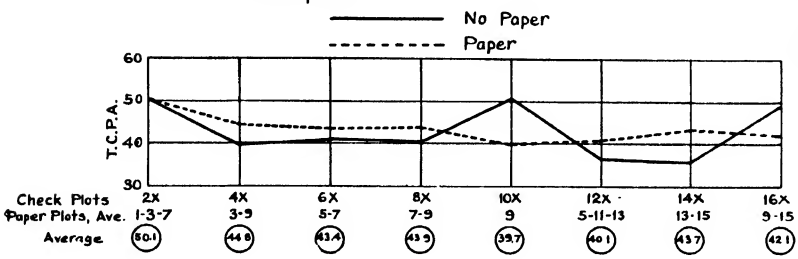
Pioneer Mill Co. Exp. 65, 1928 Crop
Field A-3 Elev. 1130 Ft.
Previous crop harvested Jan. 1926. Paper laid May 20, 1926
Pabco #224, 18" wide. Harvested Dec. 18, 1927.

Graph I - Showing respective yields of cane per acre of individual plots.



Tons Cane Per Acre			
Check Plots		Paper Plots	
No.	Yield	No.	Yield
2X	50.6	1A	52.2
4X	39.3	3A	49.9
6X	41.3	5A	38.6
8X	40.3	7A	48.2
10X	50.8	9A	39.7
12X	36.2	11A	38.8
14X	36.2	13A	42.9
16X	49.5	15A	44.6
Ave	42.4	Ave.	44.3

Graph II - Showing yields of cane per acre of individual check plots and average yields of all paper plots adjacent to respective check plots.



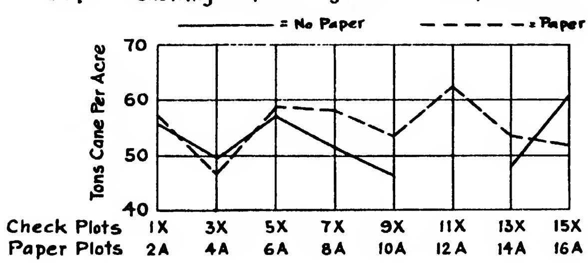
Paper Mulch Experiment

Paauhau Sugar Pl. Co. Exp. 22, 1928 Crop

Field I. Elev. about 300'

Cane-H109 3rd ratoons. Previous crop harvested Feb. 1926.
Harvested Oct. 2-4-6, 1927. Paper Pabco 224, 18" wide. Laid May 4, 1926.

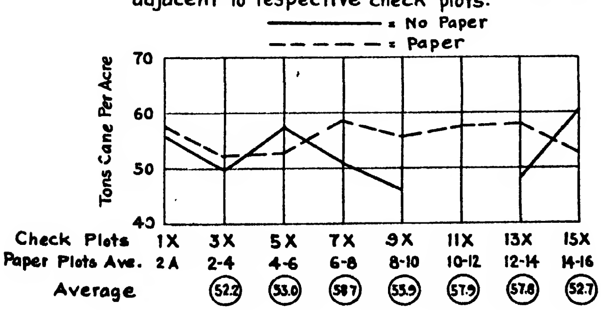
Graph I. Showing respective yields of cane per acre in individual plots.



Tons Cane Per Acre			
Check Plots		Paper Plots	
No.	Yield	No.	Yield
1 X	55.9	2 A	57.4
3 X	49.9	4 A	46.9
5 X	57.2	6 A	59.0
7 X	51.4	8 A	58.4
9 X	46.2	10 A	53.5
11 X	90.9*	12 A	62.2
13 X	47.8	14 A	53.5
15 X	60.5	16 A	51.9
True Ave.	52.7		55.4

* This figure not used in making the curve.

Graph I. Showing yields of cane per acre of individual check plots and average yields of all paper plots adjacent to respective check plots.



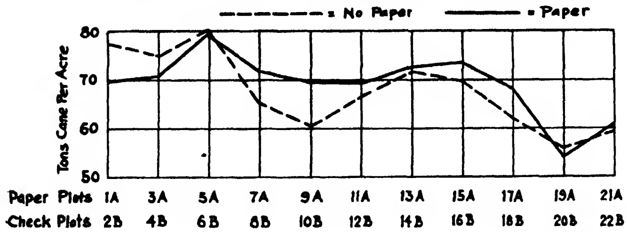
Paper Mulch Experiment

Paauhau Sugar Pl. Co. Exp. 23, 1928 Crop

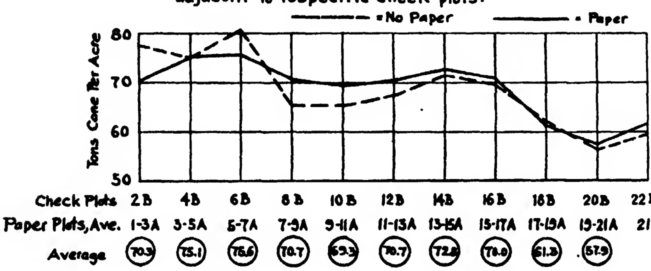
Field 9A. Unirrigated. Elev. 800'-900'

Cane-D1135 4th. ratoons. Previous crop harvested April 1926. Age 22 months.
Harvested March 7, 1928. Paper Pabco 224, 18" wide. Laid Aug. 2, 1926.

Graph I. Showing respective yields of cane per acre in individual plots.



Graph II. Showing yields of cane per acre of individual check plots and average yields of all paper plots adjacent to respective check plots.

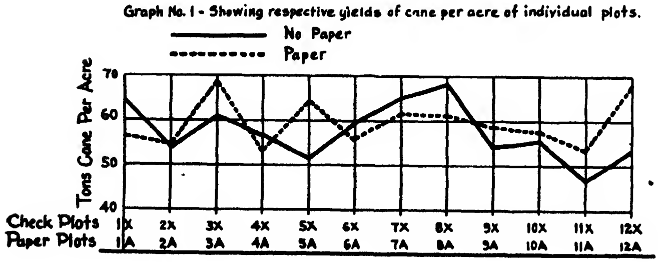


Tons Cane Per Acre			
Check Plots		Paper Plots	
No.	Yield	No.	Yield
2 B	77.7	1 A	69.9
4 B	75.0	3 A	70.8
6 B	80.4	5 A	79.4
8 B	65.4	7 A	71.8
10 B	60.5	9 A	69.6
12 B	67.1	11 A	69.1
14 B	71.7	13A	72.3
16 B	69.8	15 A	73.3
18 B	62.0	17 A	68.6
20 B	56.4	19 A	54.1
22 B	59.7	21 A	66.7
True Ave.	67.8		69.2

Waimanalo Sugar Co. Exp. 9

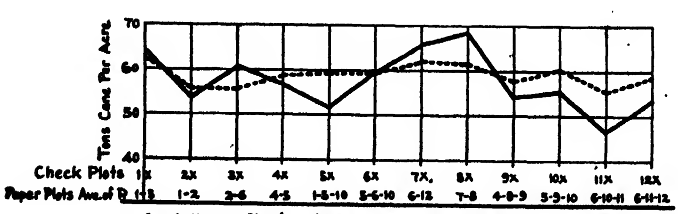
Test with Paper Mulch in Field 9.
Previous crop harvested Jan. 1926 - Paper laid March 25, 1926 - 18" Pabco Thermo-Gen No. 224.
Crop harvested Sept. 8, 1927.

Graph No. 1 - Showing respective yields of cane per acre of individual plots.



Tons Cane Per Acre			
Check	Plots	Paper	Plots
1	64.17	1	56.31
2	53.94	2	54.63
3	60.84	3	68.78
4	56.70	4	52.81
5	51.40	5	64.75
6	59.31	6	55.65
7	65.41	7	61.19
8	68.12	8	60.99
9	54.13	9	58.88
10	55.56	10	57.09
11	46.53	11	53.51
12	53.47	12	68.42
Ave.*	57.40		59.40

*Arithmetical Mean.



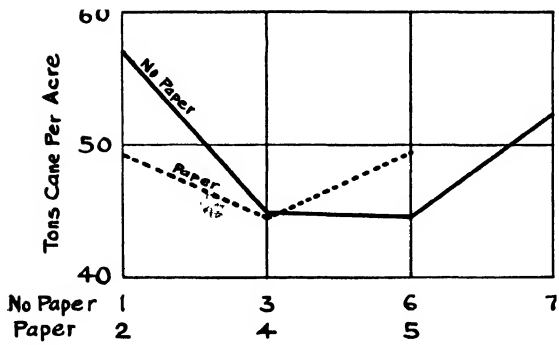
Graph No. 2 - Showing yields of cane per acre of individual check plots and average yields of all paper plots adjacent to respective check plots.

——— No Paper
--------- Paper

Wailuku Sugar Co. Exp. 17, 1927, Crop

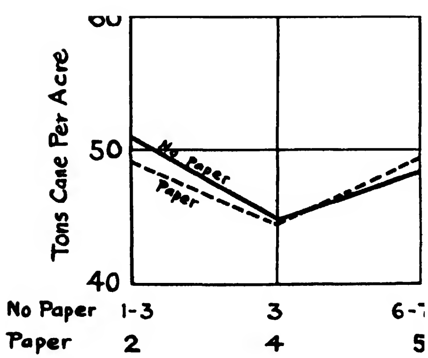
Field 69.

Previous crop harvested Dec. 1925 - Paper laid March 17 & 18, 1927 -
Pabco Thermo-Gen.* 224 - 8".
Crop harvested August 16, 1927.

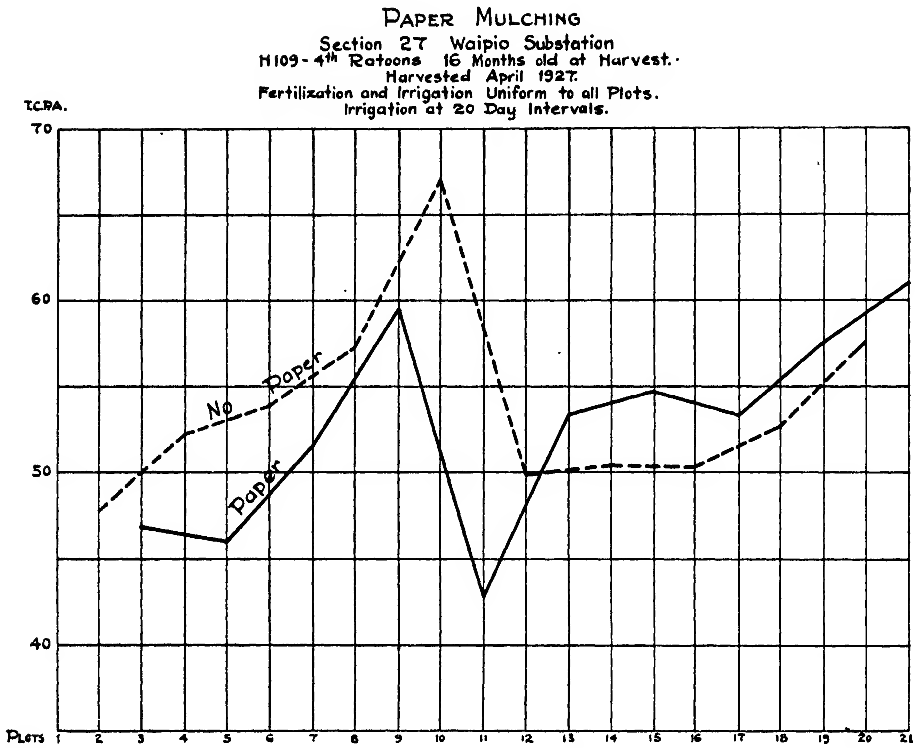


Graph No. 1. Showing respective yields of cane per acre of individual plots.

Paper	Tons Cane per acre	No Paper	Tons Cane Per acre
2	49.26	1	57.00
4	44.59	3	45.10
5	49.58	6	44.58
		7	52.41



Graph No. 2 - Showing yields of cane per acre of individual no paper plots and average yields all paper plots adjacent to respective no paper plots.



Divergence in pH

By H. A. Cook and W. R. McAllep

The application of hydrogen ion concentration to the control of raw sugar factories is comparatively recent. The development of the more detailed observations in maintaining control has brought to light several problems of interesting and complex nature. Satisfactory solutions in some cases have resulted from the limited researches we have been able to devote to the topic, while in other cases our findings are not sufficiently definite to draw final conclusions.

This investigation was undertaken to throw light on the difference in pH between limed and heated juice containing the precipitate in suspension, and a portion of the same juice from which the precipitate had been separated by filtration or decantation. This was brought to our attention by Mr. Federcell, of the Wailuku Sugar Company. It had also been observed frequently in this laboratory. Paine and Balch* comment on the difference in pH between clarified juice and the

* *Sugar*, Vol. 29, pp. 311, 416, 466. 1927. *The Planter and Sugar Manufacturer*, Vol. 78, pp. 127-148. 1927.

mud settled therefrom. An aqueous suspension of soil usually differs in pH from the clear extract. A similar peculiarity has been noticed in other solutions.

The phenomenon under investigation will be designated "divergence in pH" for want of a better term. "Divergence in pH" may be defined as the amount by which the pH of "clear juice" diverges from the pH of the "whole juice." The term "whole juice" will be used to refer to the clarified juice containing the precipitate in suspension. The term "clear juice" will refer to the filtrate from the suspended material. Usually though not always the pH of the clear juice is the lower, giving a negative value for divergence in pH.

The data given in this paper for the clear juice were obtained on a filtered portion instead of a decanted clear portion to avoid the complication due to development of acidity during the time required to secure a clear juice by settling. Samples for this investigation were prepared by liming and heating a quantity of juice. As soon as the juice was brought to the boiling point and mixed, one portion was poured onto a filter paper. A second portion was rapidly cooled to 25° C. The filtrate was also rapidly cooled as soon as a sufficient amount had been secured. pH values were determined immediately. The filter papers were neutral in reaction and did not influence the pH.

The first point determined was whether "divergence in pH" was characteristic of all or peculiar to certain juices only. Juices covering a wide range of conditions were secured from a number of sources. Portions of these juices were clarified at increasingly alkaline reactions. The pH was determined on the whole juice and on the clear juice. The results are shown graphically in Figs. 1 and 2. "Divergence in pH" is indicated by distances from the base line. Points above the base line indicate negative values, that is, lower pH in the clear than in the whole juice. Wide variations were found in individual juices; however, there were marked similarities in the majority of them. In view of this similarity the results of all of the determinations were averaged at different pH intervals. These averages, represented by the solid line in Fig. 1, are shown to give an idea of the general tendencies found and not to indicate that all juices behave in this definite manner. The two dotted lines in Fig. 1 represent individual juices, and show the extremes which were encountered. One of these juices represents the maximum divergence found and the other the minimum. Fig. 2 shows individual curves for ten of the juices and the large differences between them.

Divergence in pH was noted in all juices. The magnitude varies greatly with different juices and also in the same juice at different reactions. The clear juice is usually lower in pH, but in many of the samples divergence becomes positive at certain pH values. While juices differ to such an extent that a definite rule cannot be formulated, there are general tendencies which may be predicted with reasonable certainty. In most cases divergence is quite small below pH 6.0. From this point the curve rises very rapidly and reaches a peak between pH 6.5 and 7.0. The maximum divergence (Fig. 1) lies almost exactly at pH 6.9. From about pH 7.0 there is a very rapid decrease to a negligible amount at approximately pH 8.0. Some of the juices show a slight increase above 8.0, while others do not; divergence at this point usually being so slight that its significance may be questioned. Data in Fig. 2 will be discussed further in a later section.

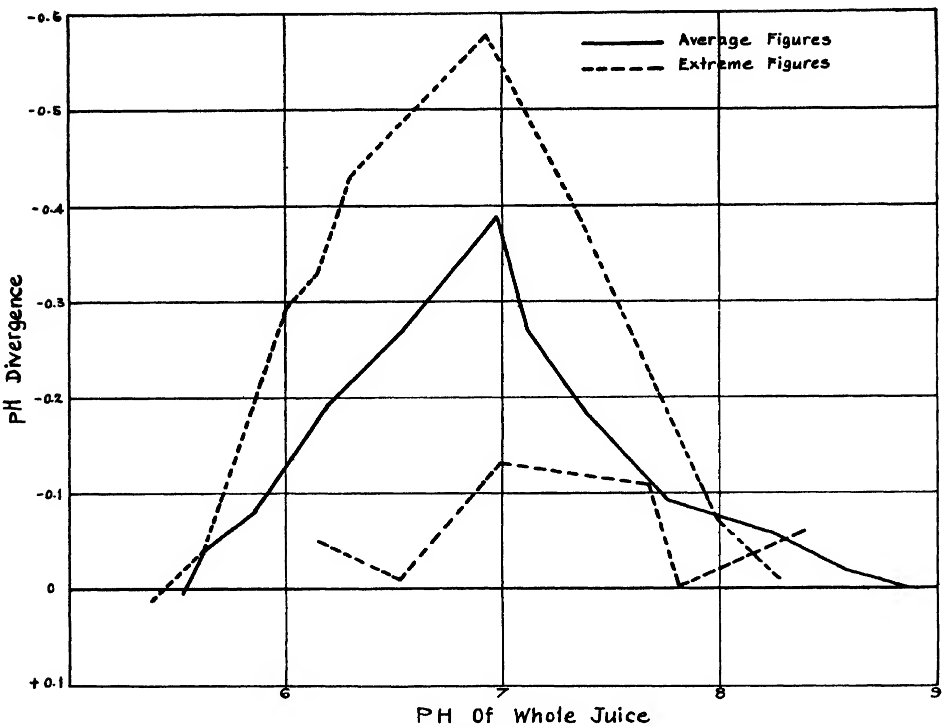

Average Figures
Extreme Figures
pH Divergence
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1
+0.1
6
7
8
9
PH Of Whole Juice

Fig. 1

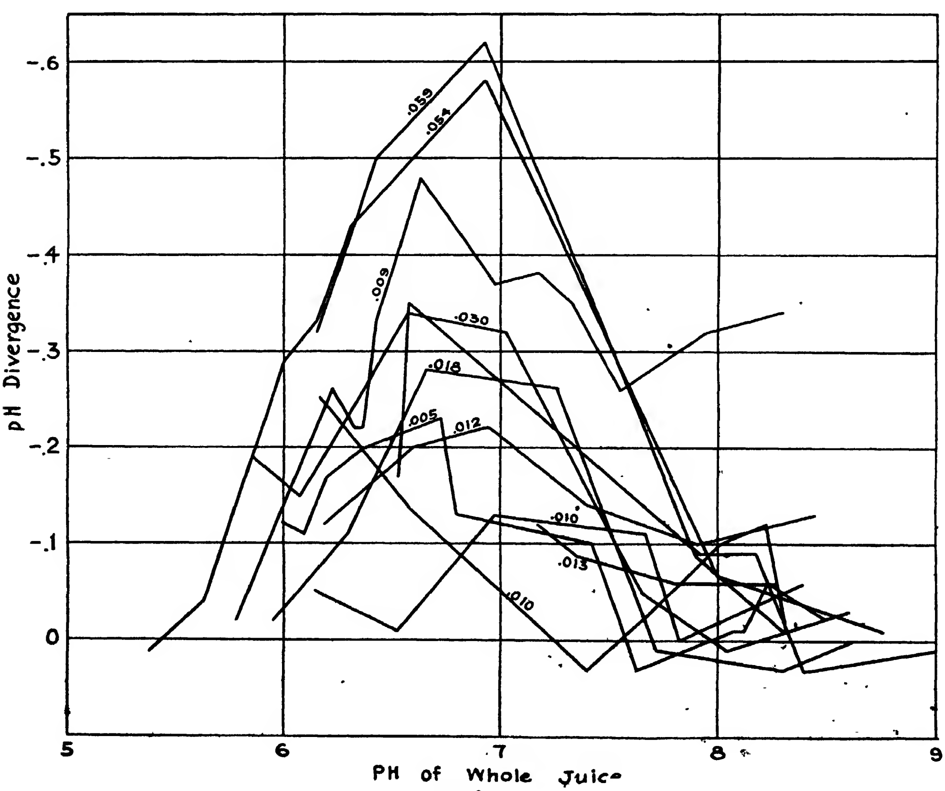

pH Divergence
-.6
-.5
-.4
-.3
-.2
-.1
0
5
6
7
8
9
PH of Whole Juice
.059
.054
.009
.030
.018
.005
.012
.010
.013
.010

Fig. 2

Colorimetric and Hydrogen Electrode Measurements

Data presented in Figs. 1 and 2 were obtained with the hydrogen electrode. Colorimetric determinations were also made on these samples. Typical results are given in the following table:

TABLE I

Divergence By:

	Hydrogen Electrode	Colorimetric
	.17	.20
	.51	.50
	.35	.25
	.09	.10
	.19	.20
	.00	.10
	.09	.10
	.37	.25
	.00	.00
	.55	.65
	.53	.40
	.58	.60
	.08	.15
	+.02	.00
	—	—
Average	.25	.24

These results may be considered mutually comparable when the sensitiveness of the colorimetric method is taken into consideration. Such close agreement between two entirely different methods is evidence that we are dealing with actual differences in pH and that the phenomenon we have termed divergence in pH is not due to peculiarities in the method used for making pH determinations.

Influence of Concentration of Precipitated Material

As stated above, the results given for clear juice were secured on samples filtered from the precipitated material. In many of the tests portions of the whole juice after heating were also allowed to settle and the pH determined on the clear juice secured in this manner. Juices passing through filter paper were clearer in nearly all instances than those obtained in the short period of settling. A comparison of results secured by filtration and by decantation appears in Table II:

TABLE II

Divergence in Filtered and Decanted Juice

	Filtered	Decanted
	.04 Very cloudy	.04 Very cloudy
	.29	.24
	.33	.22
	.43	.33
	.58	.52
	.07	.08 Very clear
	.33	.23
	.44	.31
	—	—
Average	.31	.25

In all but two cases divergence was greater in the filtered than in the settled portions. One exception was a juice clarified at an acid reaction and both the filtered and decanted portions were cloudy. The second exception was a juice that gave an exceptionally clear settled juice. Differences between filtered and decanted juices are not large but are sufficiently consistent to indicate that the small amount of precipitated material left in the decanted juice affects equilibrium conditions sufficiently to alter pH values.

Effect of Suspended and Colloidal Material

The following test is an indication that these reaction differences are not characteristic of the juice before clarification. Material not in solution was separated from individual portions of juice by three methods: (1) by filtration through filter paper, the resulting solution being slightly turbid; (2) by filtering with filter-cel, thus removing all material of larger than colloidal dimensions; and (3) by ultra-filtration through a collodion membrane, securing a filtrate free from material both in suspension and in colloidal combination. pH values follow:

TABLE III

Original juice	5.14
1. Paper filtered (slightly turbid)	5.14
2. Filter-cel filtered (clear)	5.14
3. Ultra-filtered	5.14

As the pH of the original juice and the three filtrates are identical it is evident that the suspended material and colloids had not influenced reaction values.

As a study of the possible influence of suspended and colloidal material after clarification, the original juice and the three filtrates were clarified by liming and heating. The portions were limed to as near pH 7.4 (cold) as possible, a reaction at which previous results indicated a maximum divergence. pH values were determined on the whole and clear portions. The results follow:

TABLE IV

	Whole Juice	Clear Juice	Divergence in pH.
Original juice	7.12	6.50	.62
1	7.30	6.63	.67
2	7.24	6.61	.63
3	7.19	6.58	.61

The amount of divergence in the four portions differed by small amounts only. The pH of the whole juice samples varied sufficiently to account for these small differences. In this case, at least, neither suspended matter nor colloids were essential factors in bringing about divergence in pH.

Influence of Undissolved Lime

A suggested explanation of pH divergence was the presence of slowly dissolving particles of lime in the precipitate. Such particles should dissolve on pro-

longed heating. Accordingly six portions of a juice were limed to different reactions and heated at 100° C. for one hour; the object being to determine whether the additional time of heating would eliminate divergence in pH. Reactions on the whole juice, clear juice, and settlings follow:

TABLE V

Sample	Whole Juice	Clear Juice	Divergence	Settlings
1	6.53	6.36	—.17	7.04
2	6.59	6.24	—.35	7.08
3	7.93	7.84	—.09	8.05
4	8.17	8.08	—.09	8.27
5	8.40	8.43	+.03	8.40
6	8.99	9.00	+.01	9.03

The prolonged heating of the whole juice did not eliminate divergence. On the contrary, the above results are what might be expected from data in Figs. 1 and 2. Practically no divergence was found in Samples 5 and 6. However, these two samples were at pH values where a minimum divergence would be expected. Divergence was found in the other four samples notwithstanding the prolonged heating. In connection with the influence of the concentration of precipitated material, discussed in a previous section, we would point out that in the first four samples of this set the pH of the settlings was higher than the pH of either the clear or whole juice.

As a further study of the effect of undissolved lime, comparisons were made between samples clarified with milk of lime suspension, and a calcium saccharate solution which was free from undissolved particles. Three tests were made on a sample of juice within a range where large divergence might be expected. Results are given in the following table:

TABLE VI

Portion	CaO Treated pH			Saccharate Treated pH		
	Whole	Clear	Divergence	Whole	Clear	Divergence
1	6.51	6.06	.45	6.46	5.99	.47
2	6.73	6.27	.46	6.67	6.27	.49
3	7.02	6.63	.39	7.12	6.76	.36

Divergence is approximately the same in both cases, definitely eliminating particles of undissolved lime as an explanation of this phenomenon.

Some of the settlings (Table V) were more alkaline in reaction than the clear or whole portions of the juice. This suggested the following tests, which offer a logical explanation of divergence in pH. Samples of juice were clarified and the precipitate separated by filtration. Precipitate and filtrate were then remixed. pH data are in Table VII. The Numerals 1 and 2 designate the original juices:

TABLE VII

Sample	Whole Juice	Clear Juice	Mud	Clear Juice and Mud Remixed
1a	6.57	6.06	6.70	6.53
1b	7.13	6.58	7.17	7.03
2a	6.57	6.16	6.70	6.51
2b	7.10	6.49	7.17	7.10
2c	8.08	8.00	8.22	8.06

In all of these tests the whole juice was more alkaline than the clear juice and the mud was more alkaline than either. When the clear juice and the mud were again mixed approximately the original reaction was restored. Such slight differences as were found were probably due to unavoidable loss of some of the material during handling. An explanation of this phenomenon is advanced on the premise that an equilibrium is established between the two portions or phases, i.e., solution and solids. Each portion exerts an influence upon the other and this influence is altered when the proportions are changed. When the components are again mixed in their original relative concentrations the former equilibrium is reestablished and a reaction identical with the original is again obtained.

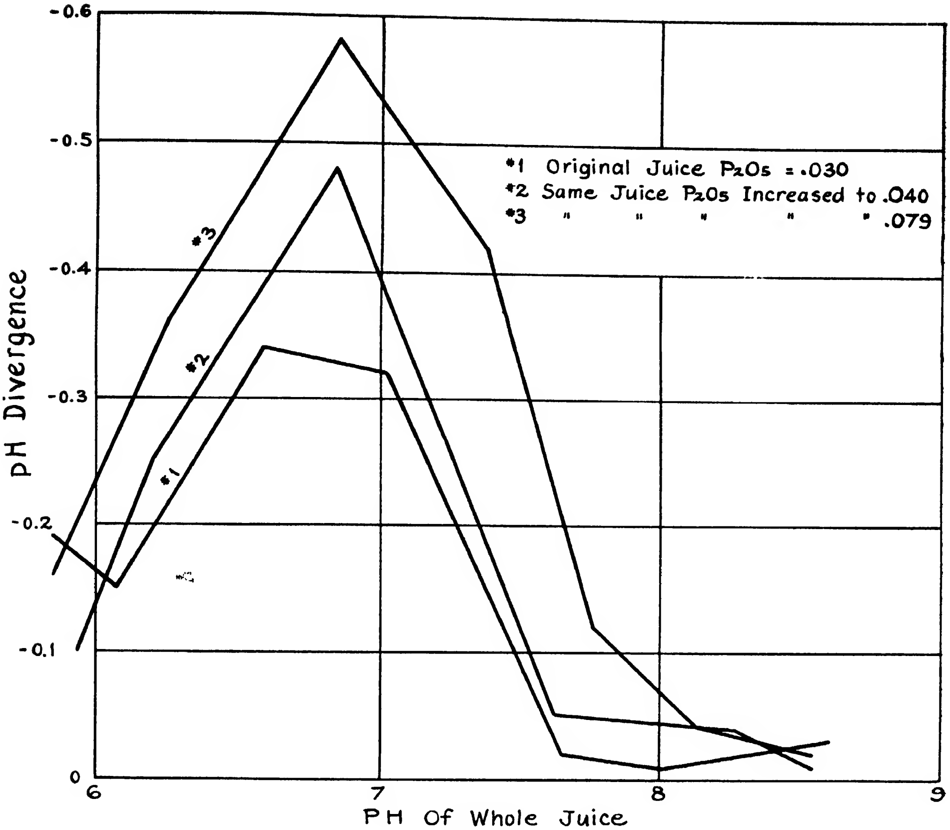
Influence of Juice Constituents

A. *Phosphoric Acid:* The foregoing tests tend to associate divergence in pH with the precipitate formed during clarification rather than with suspended matter or colloids in the original juice. Phosphoric acid is one of the principal substances precipitated during clarification. The influence of this factor was studied. Juices with varying amounts of phosphoric acid were clarified at different reactions. These results are given in Fig. 2. The small figures on each line indicate the per cent of phosphoric acid originally present in the juice. Data for these juices at the point of maximum divergence together with the original phosphoric acid content are in the following table:

TABLE VIII

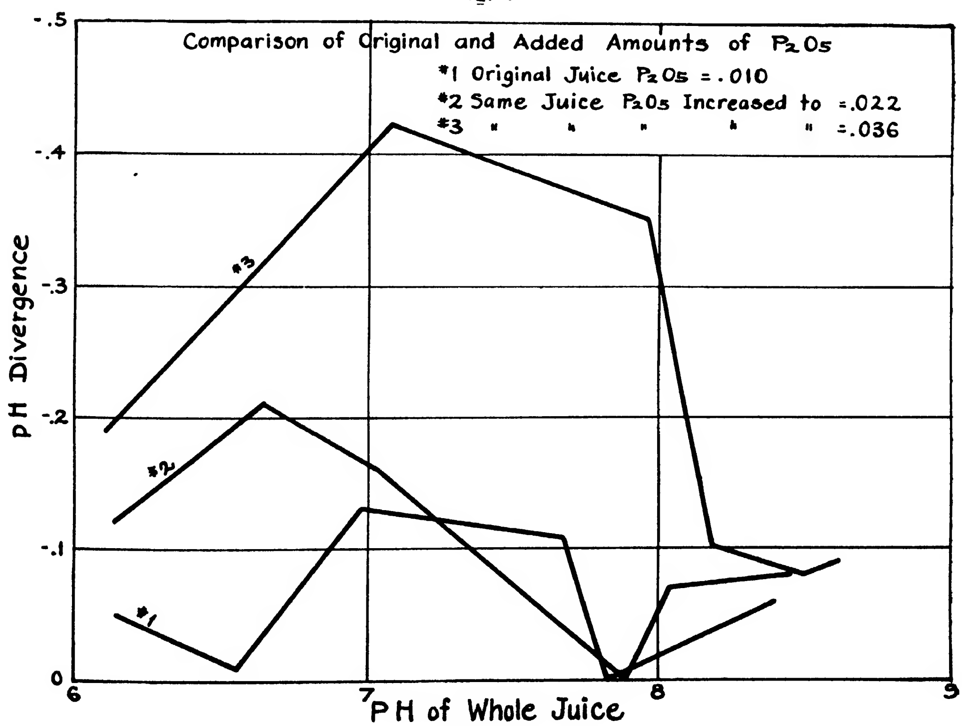
	pH at Point of Largest Divergence		
P_2O_5	Whole	Clear	Divergence
.059	6.93	6.29	.64
.054	6.93	6.35	.58
.030	7.02	6.70	.32
.018	7.26	7.00	.26
.013	7.17	7.05	.12
.012	6.95	6.73	.22
.010	6.97	6.84	.13
.010	6.58	6.44	.14
.009	6.97	6.60	.37
.005	6.79	6.66	.13

Six of the ten juices indicate a quite direct relationship between the amount of phosphoric acid and maximum divergence while a wide variation is shown in the other four.



-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
6
7
8
9
pH Divergence
PH Of Whole Juice
#1 Original Juice P2O5 = .030
#2 Same Juice P2O5 Increased to .040
#3 " " " " " .079
#3
#2
#1

Fig. 3



Comparison of Original and Added Amounts of P2O5
#1 Original Juice P2O5 = .010
#2 Same Juice P2O5 Increased to =.022
#3 " " " " " =.036
-.5
-.4
-.3
-.2
-.1
0
6
7
8
9
pH Divergence
PH of Whole Juice
#3
#2
#1

Fig. 4

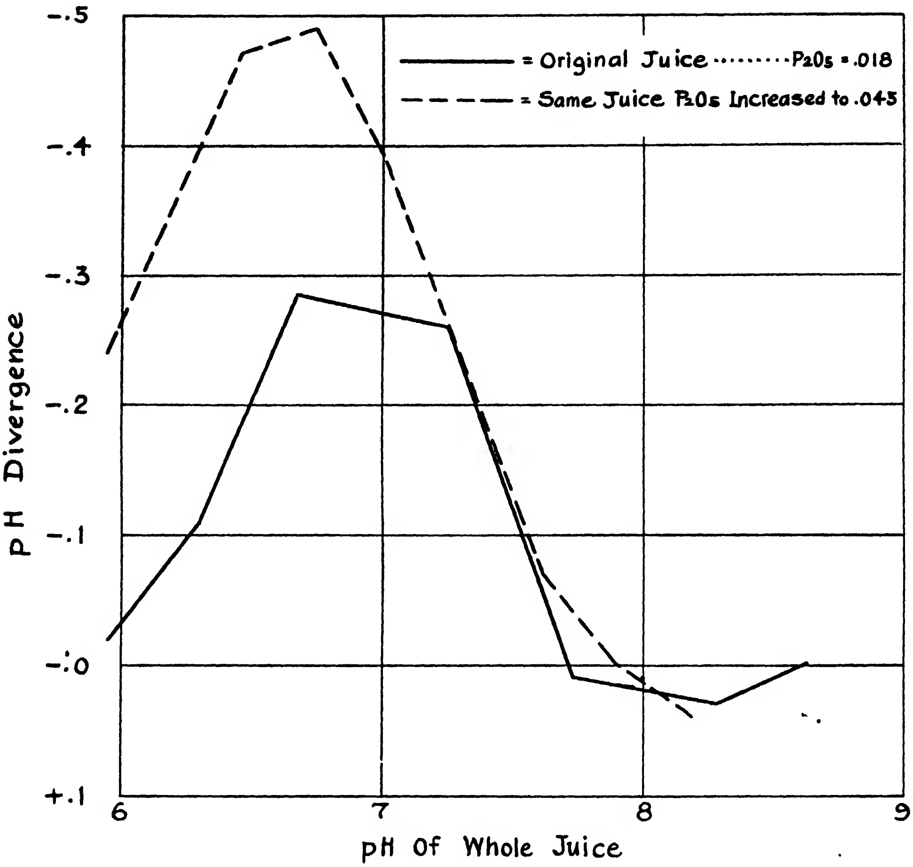


Fig. 5

Phosphoric acid was added to samples of juice to note the effect of increasing this substance. Portions of these juices were clarified at different reactions, both before and after the addition of phosphoric acid. The results of these tests are shown in Figs. 3, 4 and 5. Curves show quite consistent agreement between the amount of phosphoric acid and divergence in pH. There are some irregularities, a part of which may be due to the fact that the added phosphoric acid was not in the same chemical combination as that originally present in the juice. Divergence was increased in all three juices by the added phosphoric acid, and the maximum point was secured where divergence was shown to be greatest in Fig. 1.

A comparison was made between three juices ranging from a medium to a high phosphoric acid content and three juices originally low in phosphoric acid to which phosphoric acid was added. Phosphoric acid was added to the juices of originally low content to bring the total amount as near as possible to that contained in the other three. These juices were clarified at different reactions and the pH of the whole and clear portions determined. Results are shown in Fig. 6. Juices to which phosphoric acid was added are represented by broken lines and those to which phosphoric acid was not added by solid lines. Figures indicating the per cent P_2O_5 before clarification are given.

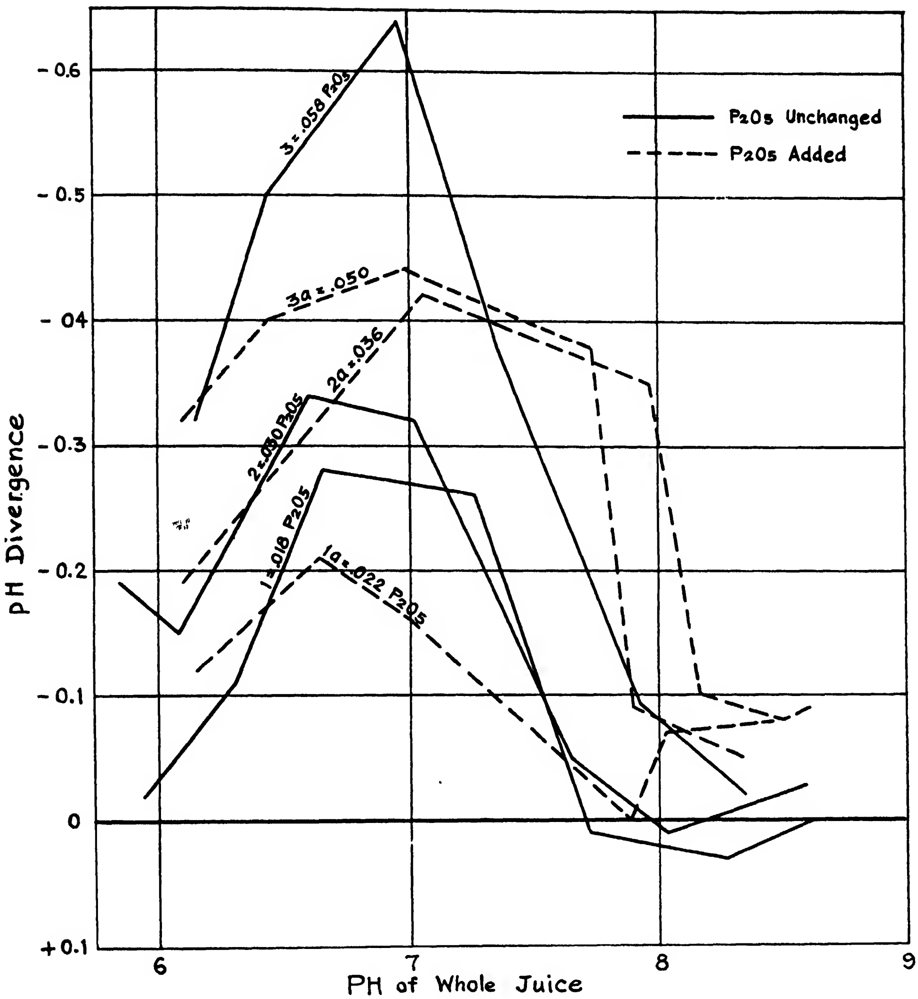


Fig. 6

A close correlation between P_2O_5 and divergence is again indicated. Two of the three sets show a greater maximum divergence with increasing amounts of phosphoric acid, regardless of whether this was originally present or had been added. An exception occurred in the juice containing the smallest amount of phosphoric acid, i.e., .018 gm. per 100 cc., and the maximum divergence was greater than in the juice to which the amount had been increased to .022. The points of maximum divergence in two of the juices to which phosphoric acid was added are at almost exactly the same pH as in the two juices with which they were compared. In the other comparison (No. 2) phosphoric acid gave a point of maximum divergence at a higher pH than was found in the original juice. The curves submitted indicate at least a systematic relationship between phosphoric acid and divergence.

An attempt was made to compare the results found in juices with those in a pure sugar solution containing phosphoric acid. Pure sugar was used to eliminate

the effect of other impurities which occur in the juice. As it is extremely difficult to make accurate pH determinations on unbuffered solutions of sucrose, the figures are not included; however, the results were very similar to those found in juices. The maximum divergence was located at a reaction very close to that shown for juice samples.

Divergence was also found when aqueous solutions of phosphoric acid were treated with lime and heated.

All of these tests indicate a relationship between phosphoric acid and pH divergence. The tests show a decided tendency for high phosphoric acid content to be associated with a large divergence and conversely low concentrations of phosphoric acid produce variations of lesser magnitude. The addition of phosphoric acid usually increases divergence in pH. The relation is definite enough to identify phosphoric acid as a factor influencing this phenomenon. It is evident, however, that it is not the only factor involved.

B. *Influence of Iron, Alumina and Silica:* While determining the effect of phosphoric acid in pure sugar solutions, tests were also made using salts of iron,

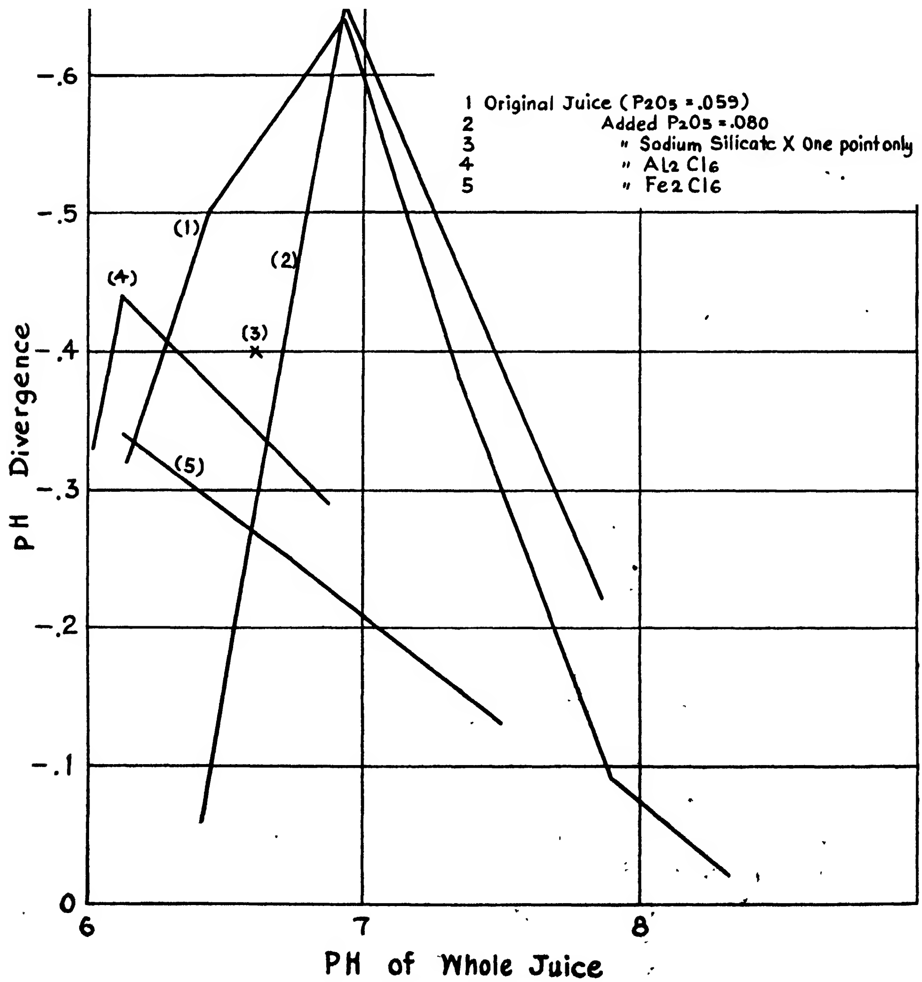


Fig. 7

alumina and silica in pure sugar solutions. The pH values are subject to the objections mentioned in connection with phosphoric acid and pure sugar solutions; however, the results indicated that all of these salts influenced pH divergence. Divergence between whole and clear portions was found when aqueous solutions of these salts were treated with lime and heated. Due to the relative insolubility of iron and aluminum in combination with phosphoric acid at the natural pH of the raw cane juice it would seem that small amounts only of either would be present in juices. However, the results indicated that even small amounts of these substances would influence divergence.

Additions of these salts were made to two different juices. One of the juices was from Makiki plots with high P_2O_5 content. The second was mixed juice of low P_2O_5 content from Oahu Sugar Company. The results are shown in Figs. 7 and 8.

The addition of phosphoric acid to the juice already high in this substance produced but little change in divergence (Fig. 7), while its addition to the juice low in P_2O_5 (Fig. 8) caused a material change in this respect. The number of portions to which sodium silicate was added was insufficient to warrant satis-

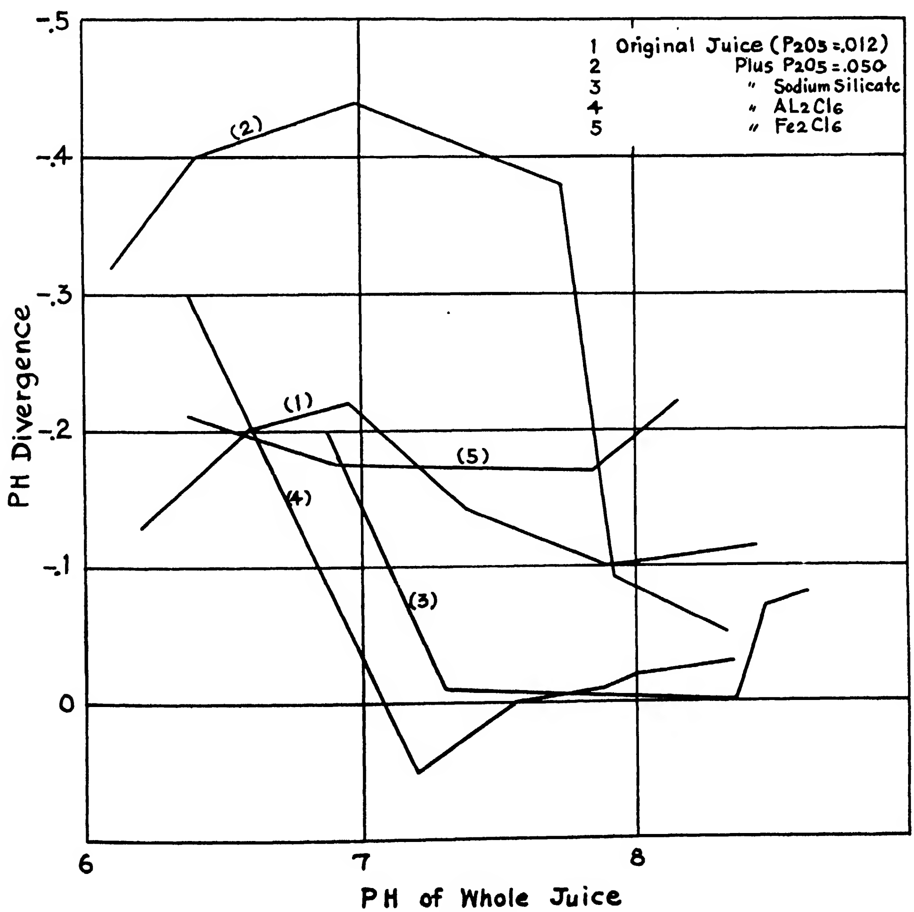


Fig. 8

factory conclusions. A silicate compound more nearly characteristic of that in cane juice was not available, and the compound on hand was not satisfactory for this work. Additions of iron and aluminum salts tended to change the character of the juice materially. The addition of iron resulted in less pronounced divergence, the peak of which occurred at a more acid reaction and the divergence remained more nearly constant over a wider range of reaction. Aluminum reduced the amount of divergence in the first juice and increased it in the second. It also gave a peak in the curve at a lower pH.

Phosphoric acid seems to be the predominating factor when the juice contains fairly large amounts of this substance. In this case the maximum divergence is large and occurs in the neighborhood of pH 7.0. At lower concentrations of phosphoric acid the point of maximum divergence tends to shift toward a lower pH. Data in Figs. 7 and 8, indicate that additions of iron and aluminum cause maximum divergence to occur at a lower pH. This suggests the explanation that as the amount of phosphoric acid decreases, the influence of these other precipitates becomes greater. Titration curves of combinations of these substances point to the same conclusion. When phosphoric acid is present in excess in combinations of silica, iron and aluminum the titration curve takes the shape characteristic of phosphoric acid. If phosphoric acid is not in excess there is a reaction between the iron and phosphoric acid and the curve takes the shape of a typical aluminum titration curve. The effect of silica on the shape of the curve is very slight, especially when the amount of phosphoric acid is high. It would seem that variations in the concentration of phosphoric acid, iron and alumina would account for much of the irregularity in pH divergence shown in Fig. 2.

The experiments strongly indicate that precipitates formed when cane juice is clarified with lime are the cause of divergence in pH. From this point of view all of the precipitates formed during clarification might be expected to influence this phenomenon, yet phosphoric acid, iron and aluminum seem to account for a large part of it.

Conclusions

1. Divergence in pH was found in all juices studied.
2. Colorimetric and hydrogen electrode measurements indicate that divergence is a real pH difference.
3. The concentration of the suspended precipitate influences divergence.
4. Divergence was not found in juices before clarification.
5. The tests made in this investigation do not indicate that suspended or colloidal material in juices is a factor influencing divergence.
6. Divergence in pH is not due to undissolved lime particles.
7. There is a systematic relationship between the phosphoric acid content and pH divergence.
8. Other precipitable constituents of the juice, such as iron and aluminum, influence divergence in pH.
9. These data indicate that the probable explanation of divergence in pH is the mutual co-dependence of solution and precipitate. At any given concentration

of solution and precipitate an equilibrium is established. This equilibrium is evidently a factor influencing the pH of the mixture. With a change in the relative concentration of solution and precipitate this equilibrium is changed with a resulting change in pH.

Relation to Factory Control

Divergence in pH is of material significance from the standpoint of pH control of factory operation. All Experiment Station data on clarification refer to the pH of the clear, hot-limed juice. Tests for clarification control should be made, therefore, on a portion of the hot-limed juice from which the precipitate has been separated. Within the range recommended for the reaction of the hot-limed juice, 8.0-8.3 pH, the error due to testing the turbid, instead of the clear juice, will usually be small, though even in this range divergence amounting to as much as .3 pH has been found in some juices. As the clarification pH decreases, the error due to making these tests on turbid juice increases, and the results become so misleading that they are of little value for control purposes. As divergence varies greatly in different juices it is impracticable to apply a correction, and the only alternative is to make pH tests for clarification control on the clear juice.

On the other hand, the agreement between colorimetric and hydrogen electrode determinations gives quite definite evidence that the pH determined in the presence of the precipitate is the actual pH of the turbid juices or settlings. From the standpoint of inversion velocity the pH determined in the presence of the precipitate should be considered the significant figure as long as the precipitate remains in suspension. For instance, in the case of settlings the pH of the settlings and not the pH of the clear juice separated therefrom should be considered as the pH related to inversion velocity.

Acknowledgment

This opportunity is taken to acknowledge the many suggestions and material assistance given by Dr. Hance during this investigation, and also to acknowledge the kindly cooperation of Mr. Stewart, Mr. Hansson, Mr. King, and Mr. McGeorge.

The Preservation of Cane Seed

By R. E. Doty

Introduction

Owing to the fact that sugar cane seed loses vitality very rapidly, it has previously been necessary to plant the fuzz in germination flats very soon after the tassels have been cut. To handle large quantities of fuzz so quickly would require extensive equipment, which would be in use for only a short time each year. In addition to this, the weather conditions during tassel season are particularly

adverse to such a program. Therefore it was especially desirable to develop practical means of overcoming the many difficulties encountered in the germination of new cane seedlings.

Previous Work

Some plant physiologists have pointed out that there is an actual respiration (1, 2) or oxidation that goes on in the seeds under normal conditions of storage. Respiration seems to increase with temperature and the moisture content of the seeds.

Because of the relatively high humidity as well as temperature in Hawaii, seeds of all kinds deteriorate rapidly when exposed to the open air. Cane seed is particularly sensitive in this respect.

C. F. Kinman and T. B. McClelland (3) reported that vegetable seed kept very well stored in air tight jars in the bottom of which was placed a small quantity of calcium chloride. This method proved so satisfactory to them that it was recommended for general use.

D. A. Cooke (4) reported great improvement in the keeping qualities of cane seed preserved in calcium chloride with carbon dioxide or hydrogen in a constant temperature of 68° F.

As the calcium chloride method is very simple, it was determined to study it further with a view of working out a practical scheme for the handling of rather large quantities of cane fuzz.

Experimental Work

The plan of the present endeavor was to determine the influence of the factors considered important in causing the deterioration of cane seed being held for future planting.

The factors moisture, temperature and oxygen supply alone and in combination were studied in the various treatments discussed in this paper.

The work was begun in December, 1926, when the collection of a sufficient quantity of fuzz material was undertaken. On December 10 and 14, Y. Kutsunai supervised the collection of some 1900 tassels of Yellow Tip x H 109 from Field 15, Waimanalo Sugar Company. These tassels were air-dried in flour bags, the fuzz stripped from the stems and all of the fuzz material placed in 2 large sized garbage cans. This fuzz was thoroughly mixed to give uniformity as to quality. One hundred and forty two-pound coffee tins with tight friction lids were obtained from the American Can Company.

An equal quantity of fuzz was placed into each of these tins. It was found that approximately the same amount of fuzz would stay in each can if they were filled and thoroughly jarred down; the shaking and filling being continued until no more fuzz would stay in or on the can. The fuzz was so light and fluffy that it was impractical to weigh each can of fuzz. A total of 9 cans were used in each specific treatment. These were handled as a unit and treated exactly alike. Three cans were taken from each set and the fuzz planted at the end of 3 months, 3 cans at the end of 6 months, and the last 3 cans at the end of 9 months. According

to the specific treatment desired, air, oxygen or carbon dioxide was introduced into the cans. Also a small one-pound tin, containing a small amount of calcium chloride and covered with cheesecloth, was placed in each can. The exact amount of calcium chloride was determined by the specific treatment.

After filling and treating, all of the cans were then sealed with melted paraffin or brushed with Roger's brushing lacquer to make them air tight. The cans were segregated by label and distributed to their various storage temperatures.

One set was planted immediately to determine the number of germinations that could be obtained with fresh seed. This record served as a scale with which to judge the germinations obtained by various treatments at their respective planting times.

At the expiration of each storage period, three cans were taken from each set and the fuzz planted in the usual way. The fuzz from each can was always planted to two seed flats and carefully numbered. Each planting time required the preparation and planting of 84 seed flats. These were placed in the glass house and germinated. Counts of the germinations obtained in each flat were made 10 days after planting.

As a matter of record the detailed progress notes with dates are given herewith. The fuzz was removed from the tassels and put in large tins with $CaCl_2$ on December 17-20, 1926. All cans were filled and placed in their respective storage temperatures as planned on December 23, 1926. On December 24 the first set of three cans was planted as checks against the stored material. Two boxes planted from each can. Counts made at the age of 19 days (January 12, 1927) gave the number of germinations to be obtained from fresh seed. The following figures were obtained:

TABLE I

		No. Seedlings Germinated	
Can 1	Flat No. 1	877	
	Flat No. 2	500	1377
Can 2	Flat No. 1	728	
	Flat No. 2	771	1499
Can 3	Flat No. 1	643	
	Flat No. 2	502	1145
Average per can			1340

It should be noted here that this is very excellent germination.

It was also deemed advisable to determine the best time to make the counts of germinations in this test.

Accordingly some extra seed that had been canned for 44 days in $CaCl_2$ and CO_2, stored in a temperature of 75° F. was planted on February 2, 1927. Counts were made at intervals and the mortality noted.

The data obtained are given in the following table:

TABLE II

STORED AT 75° F. $CaCl_2$—25 GMS. PER 1000 cc. SPACE; CO_2 GAS

SEED YELLOW TIP x H 109

Can No.	Box No.	Canned Dec. 20, 1926 Date Seed planted	Feb. 8, 1927 6 days planted No.	Totals	Feb. 10, 1927 8 days planted No.	Totals	Feb. 12, 1927 10 days planted No.	Totals	Feb. 14, 1927 12 days planted No.	Totals	Feb. 19, 1927 17 days planted No.	Totals
			Planted Feb. 2, 1927—Seed 44 days old									
1	1	Feb. 2, 1927	417		431		397		364		360	
	2	"	441		451		401		347		345	
				858		882		798		711		705
2	1	Feb. 2, 1927	368		372		350		295		291	
	2	"	376		383		369		322		322	
				744		755		719		617		613
		Average		801		818.5		758.5		664		659

These data are shown graphically in Fig. I.

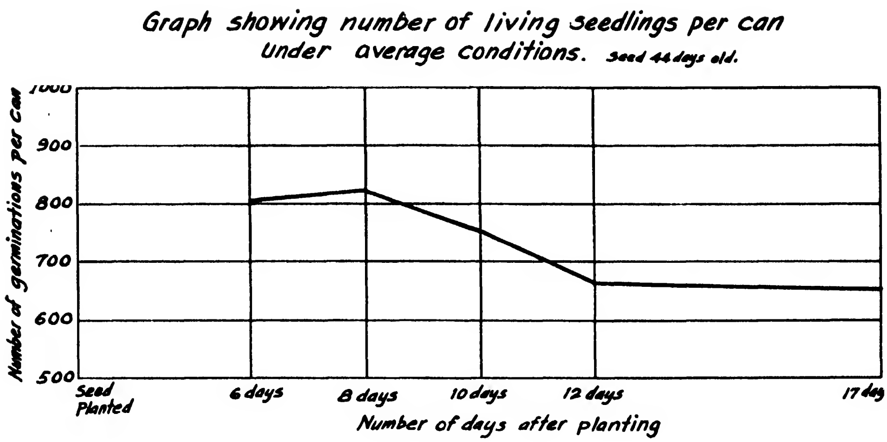


Fig. 1

From these data it is seen that there is a decline in the number of living seedlings from 8 days after planting to the end of the test (17 days); though the losses after 12 days were very small. This mortality amounted to an average of 159.5 plants out of 818.5 or 19½ per cent. It has been noted in all of the seedling work that there was considerable mortality even with the best of care.

Tabulated Data of Treatments

The details of the different treatments and the results are given:

A Series:

The moisture, air, CO_2 and oxygen were variables in this group of tests. The temperature was maintained uniform and constant at 68° F. Calcium chloride was used uniformly at the rate of 25 grams per 1000 cc. of space throughout this series wherever it was called for.

Three cans were planted on each of the following dates: April 11-12, June 17-18, and September 16, 1927.

(1) A-1 lot treated with $CaCl_2 + CO_2$.

	No. of germinations per can		
Can No.	Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	183	28	25
2	184	17	29
3	202	7	41
Average	186.3	17.3	31.6

Result—poor germination.

(2) A-2 lot treated with CO_2 only.

	No. of germinations per can		
Can No.	Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	0	0	0
2	3	0	0
3	4	0	0
Average	2.3	0	0

Result—no germination after 3 months' storage.

(3) A-3 lot treated with $CaCl_2$ + Air only.

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	84	4	339*
2	79	17	44
3	104	90	"M"
Average	89	37	127

Result—Rather poor germination except in one case at 9 months. All seedlings were very weak and died in a few days.

(4) A-4 lot treated with $CaCl_2$ + Oxygen.

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	32	3	24
2	52	38	3
3	29	4	"M"
Average	37.6	15	13

Result—Distinctly inferior to air and $CaCl_2$. All seedlings died. Oxygen seemed to accelerate deterioration of seed at 68° F.

(5) A-5 lot treated by being dried for 5 days in electric oven at 32°-35° C. and then sealed air tight in cans.

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	610	49	2
2	329	10	26
3	339	0	0
Average	426	19.3	9.3

Result—Germinated well at 3 months, but practically failed to keep longer.

NOTE—"M" indicates that this can was given to the genetics department for some special study.

B Series:

Temperature was the variable in this group of treatments. The amount of calcium chloride was uniform. (25 grams per 1000 cc. space.)

Carbon dioxide was used uniformly in the first four lots. Air was used in place of carbon dioxide in the last two lots (Nos. B-5 and B-6).

The number of cans used per treatment and dates of storage and planting are the same as in the "A" series.

(1) B-1 lot stored in normal air temperature (mean 75° F.).

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	89	20	0
2	250	6	0
3	183	17	3
Average	174	14.3	1

Result—Rapid decline in viability. Poor germination.

---

* Better glass house technic enabled us to germinate more, but they were so weak that they died.

(2) **B-2 lot stored at 68° F.**

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	171	67	11
2	162	37	17
3	217	30	15
Average	183.3	44.6	14.3

Result—Some improvement over normal air temperature. Checks very close with lot A-1 which was handled exactly like this lot.

(3) **B-3 lot stored at 38° F.**

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	143	54	337
2	383	112	353
3	187	333	571
Average	237.6	166.6	420

Result—Marked improvement in germination with lower storage temperature.

(4) **B-4 lot stored at 31° F.**

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	575	242	420
2	639	193	650
3	169	267	"M"*
Average	461	234	535

Result—This lower storage temperature gave the best germination of the entire study.

(5) **B-5 lot stored at 38° F., but air used instead of CO_2.**

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	203	52	595
2	154	81	171
3	179	129	113
Average	178.6	87	293

Results—This germination is not as good as B-3 which has same storage temperature, but had CO_2 in place of air alone. This lot stored in air at 38° F. is distinctly better than A-3, stored with air at 68° F. (See graph in Fig. 5.)

(6) **B-6 lot stored at normal temperature (mean 75° F.), using air instead of CO_2.**

Can No.	No. of germinations per can Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	16	0	0
2	113	0	0
3	44	3	0
Average	43	1	0

Result—Seeds stored in $CaCl_2$ with air only at normal air temperature are little better than no storage at all.

C Series:

In this series the amount of calcium chloride was varied.
Temperature was maintained constant and uniform at 68° F.
Carbon dioxide was used uniformly throughout.

* One can given to Dr. Mangelsdorf for special study, so average is for 2 cans only.

(1) **C-1 lot treated to small amount of $CaCl_2$.**

(9 gms. $CaCl_2$ to 1000 cc. air space).

	No. of germinations		
Can No.	Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	530	272	239
2	643	303	375
3	653	426	"M"
Average	608.6	333.3	307

Result—This germination is the best of all lots stored at 68° irrespective of any other treatment. At three and six months it is even better than the lot (B-4) stored at 31° F., though at 9 months the seed at 31° F. germinated best.

(2) **C-2 lot treated with medium amount of $CaCl_2$.**

(25 gms. $CaCl_2$ to 1000 cc. space).

Approximately this amount used as a constant in all of "A" and "B" Series.

	No. of germinations		
Can No.	Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	121	11	14
2	199	26	8
3	151	9	11
Average	157	15.3	11 (Plants weak)

Result—Poor germination. Apparently this amount of $CaCl_2$ is decidedly too much.

(3) **C-3 lot treated with a large amount of $CaCl_2$.**

(60 gms. $CaCl_2$ to 1000 cc. space).

	No. of germinations		
Can No.	Stored 3 mos.	Stored 6 mos.	Stored 9 mos.
1	12	0	0
2	17	0	1 died
3	21	0	2 died
Average	16.6	0	1 died

Result—This gives further evidence that too much $CaCl_2$ will kill the seed. It is possible to use too much $CaCl_2$ as well as too little.

TABLE III

SUMMARY

Check seed planted immediately averaged 1340 germinations per can (See Table I).

Averages of each treatment.

Germinations per can.

(From tabulated data of treatments.)

A Series

Uniform Temp. 68° F.—$CaCl_2$ 25 gms. per 1000 cc. space).

Series	Treatment	Stored 3 mos.	Stored 6 mos.	Stored 9 mos.*
A-1 lot	$CaCl_2 + CO_2$	186.3	17.3	31.6
A-2 lot	Co_2 only	2.3	0.0	0.0
A-3 lot	$CaCl_2$ + air	89.0	37.0	127.0†
A-4 lot	$CaCl_2$ + oxygen	37.6	15.0	13.0
A-5 lot	Air-dried electric oven 33-35° C.—5 days	426.0	19.3	9.3

(Data graphically shown in Fig. 2 and Fig. 6.)

See B 6—same treatment at 75° F.

* Some good germinating lots gave lower counts at 6 months than at 9 months due to insufficient watering during a hot day immediately after sprouting.

† Discard—erratic due to some unknown factor. Seedling died in a few days.

B Series

Uniform $CaCl_2$ (25 gms. per 1000 cc. space).

Variable temperature.

	B-1 lot Normal air temperature (75° F.)	174.0	14.3	1.0
CO_2 uniform	B-2 lot CO_2 at 68° F.	183.3	44.6	14.3
	B-3 lot CO_2 at 38° F.	237.6	166.6	420.0
	B-4 lot CO_2 at 31° F.	461.0	234.0	535.0
Air uniform	B-5 lot Air at 38° F.	178.6	87.0	293.0
	B-6 lot Air at 75° F.	43.0	1.0	0.0

(Data shown graphically in Fig. 3 and Fig. 5).

C Series

Uniform 68° F. and uniform CO_2.

Variable—amount of $CaCl_2$.

C-1 lot 9 gms. $CaCl_2$ per 1000 cc. space	608.6	333.3	307.0
C-2 lot 25 gms. $CaCl_2$ per 1000 cc. space	157.0	15.3	11.0
C-3 lot 60 gms. $CaCl_2$ per 1000 cc. space	16.6	0.0	1.0

(Data shown graphically in Fig. 4).

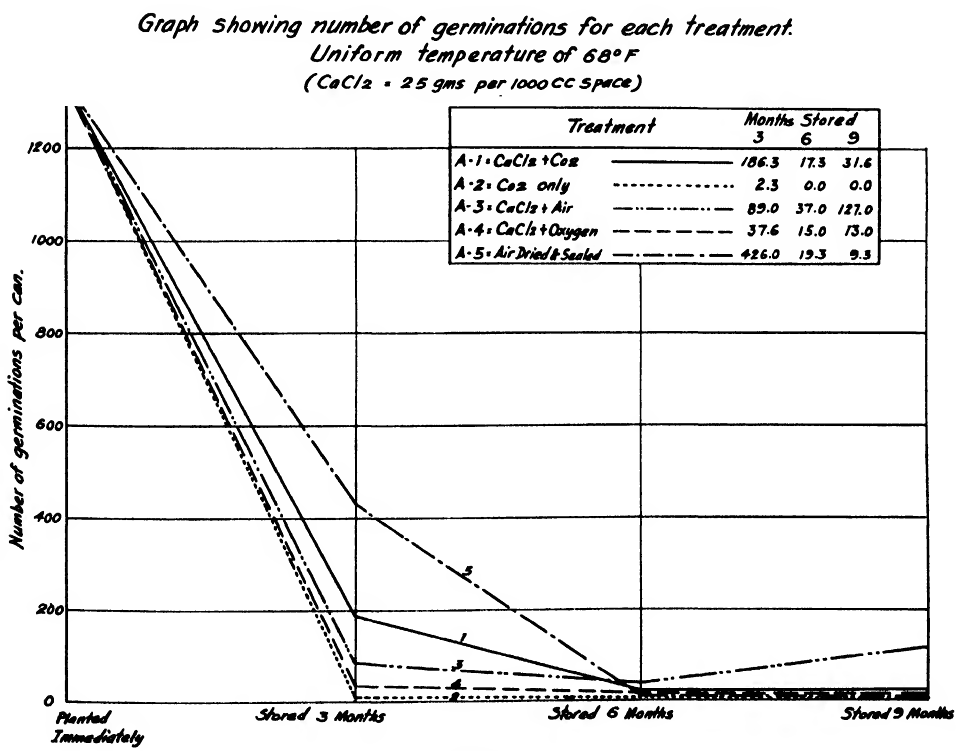


Fig. 2

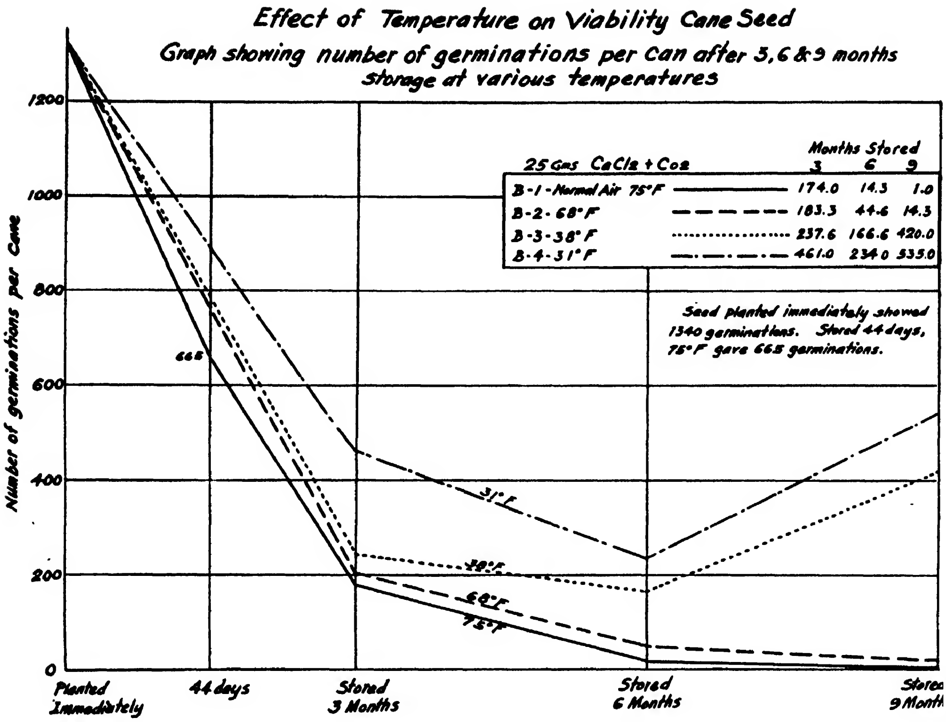

Effect of Temperature on Viability Cane Seed
Graph showing number of germinations per Can after 3, 6 & 9 months storage at various temperatures
25 Gms CaCl2 + Co2
Months Stored
3 6 9
B-1-Normal Air 75°F 174.0 14.3 1.0
B-2-68°F 183.3 44.6 14.3
B-3-38°F 237.6 166.6 420.0
B-4-31°F 461.0 234.0 535.0
Seed planted immediately showed 1340 germinations. Stored 44 days, 75°F gave 668 germinations.
668
31°F
38°F
68°F
75°F
Number of germinations per Cane
1200
1000
800
600
400
200
0
Planted Immediately
44 days
Stored 3 Months
Stored 6 Months
Stored 9 Months

Fig. 3

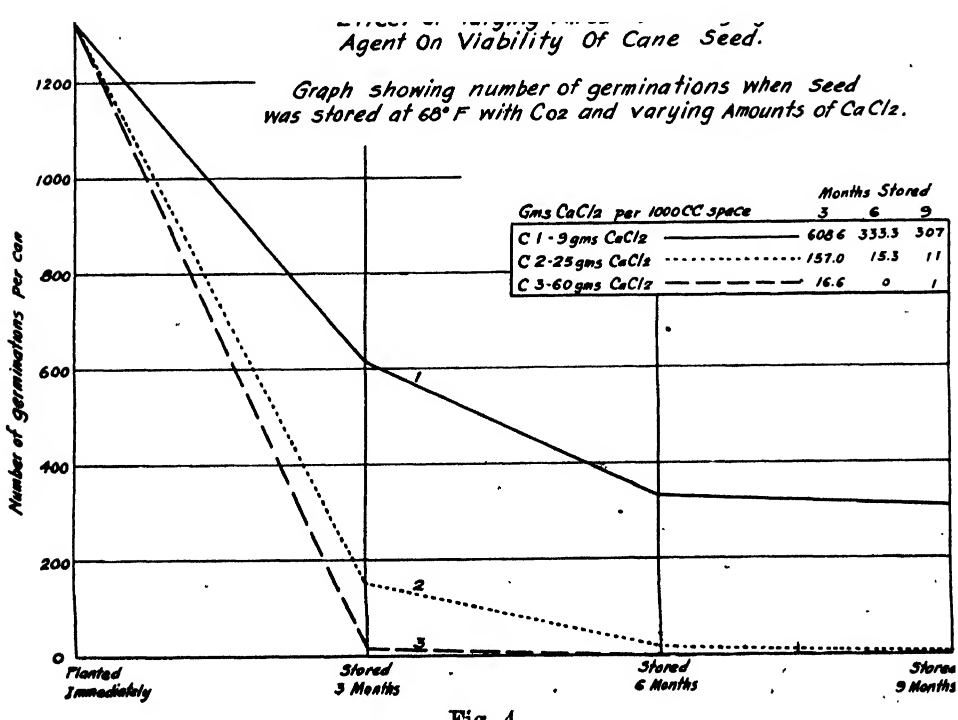

Agent On Viability Of Cane Seed.
Graph showing number of germinations when seed was stored at 68° F with Co2 and varying Amounts of CaCl2.
Gms CaCl2 per 1000CC space
Months Stored
3 6 9
C 1-9 gms CaCl2 608.6 333.3 307
C 2-25 gms CaCl2 157.0 15.3 11
C 3-60 gms CaCl2 16.6 0 1
1
2
3
Number of germinations per can
1200
1000
800
600
400
200
0
Planted Immediately
Stored 3 Months
Stored 6 Months
Stored 9 Months

Fig. 4

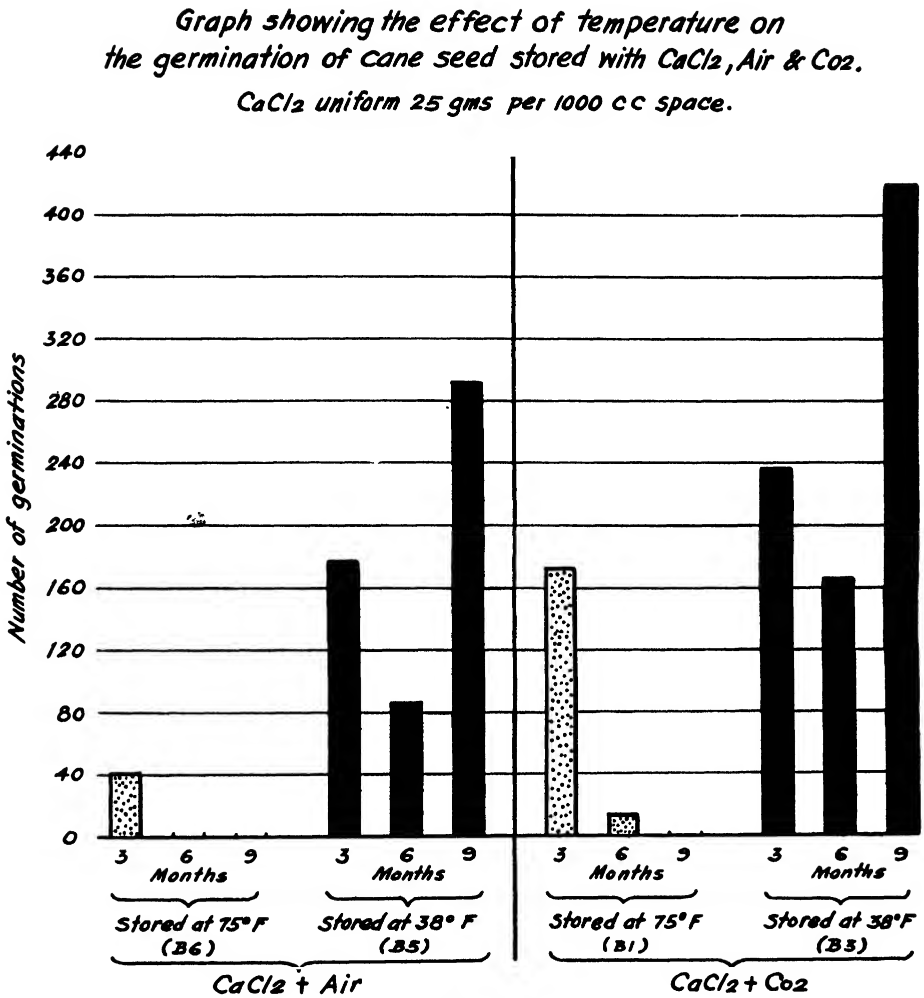


Fig. 5

Discussion

This study emphasizes the short life of a cane seed.

At best, the viability of the seed declined rapidly during the first three months of storage. No doubt, much of this decline can be accounted for in that there are large numbers of weak seedlings which germinate in the fuzz that is planted immediately after gathering, but which die in 8 to 12 days. These weak seeds do not germinate in the stored material, so the counts are considerably lower.

Another factor contributing to low germinations in Series A and B was the excessive amount of calcium chloride that was used uniformly throughout. As noted in Series C, the optimum amount of calcium chloride to be used with air dried seed was not more than one-third of the amount actually used (25 gms. per 1000 cc. space).

The summary table (Table III) and charts bring out some interesting points. Lot C-2 using 25 gms. of calcium chloride per 1000 cc. space plus carbon dioxide

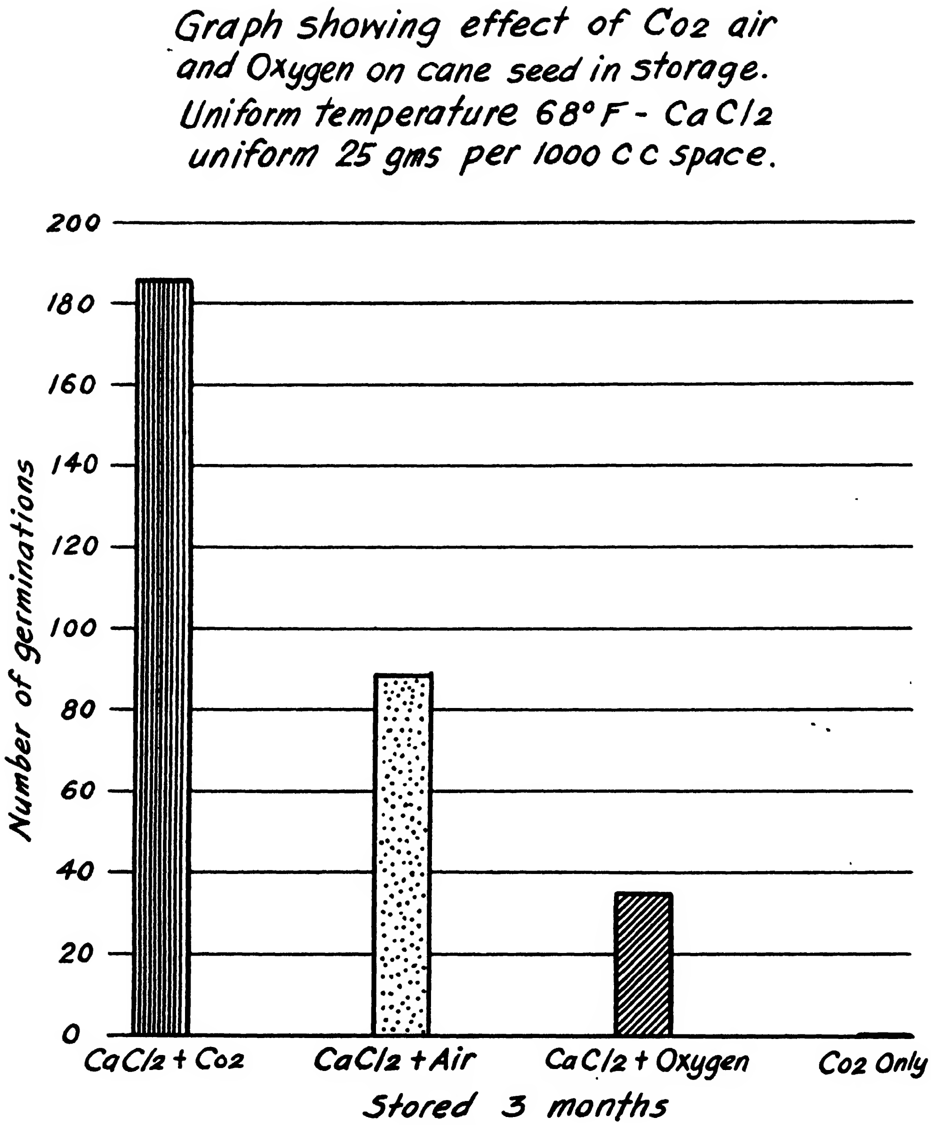


Fig. 6

gave germinations comparable with the identical treatment in B series (B-2). Note that at the end of 9 months there was a great increase in germinations from an average of 11 seedlings per can in lot C-2 (25 gms. $CaCl_2$) to 307 seedlings per can in lot C-1 (9 gms. $CaCl_2$). These results in Series C indicate that calcium chloride was used in excess in all cans stored in Series A and B. Then compare the increased germination in B series from an average of 14.3 seedlings per can in B-2 ($CaCl_2 + CO_2$ at 68° F.) to 535 seedlings per can in B-4 ($CaCl_2 + CO_2$ at 31° F.).

This gives evidence that both temperature and moisture exert a great influence on the viability of cane seed.

From Fig. 5 it also appears that temperature is a more important consideration than the particular gas medium used (CO_2 or air, etc.).

These results suggest that excellent germination may be obtained by combining the optimum preserving temperature with optimum moisture content in the presence of an inert gas such as CO_2.

Advantage of these results was taken this last seedling season (1927-1928) when large quantities of cane fuzz was stored in large sized carbide tins with the smallest amount of $CaCl_2$ (9 gms. per 1000 cc. space) and plenty of carbon dioxide. These cans were stored in the 31° F. room of the Oahu Ice and Cold Storage Company. At various times during the season there were over 200 cans in storage. The germinations from stored material were thoroughly satisfactory and allowed the planting work to continue until April when all of the important seed had been planted. It was also practical to discontinue seedling planting during unfavorable weather without great losses in viability.

Conclusions

From the study of the data obtained in this experiment the following conclusions are suggested:

(1) Cane seed may be preserved in calcium chloride and carbon dioxide and stored at 31° F. for a period as long as 9 months and still obtain healthy seedlings, though the total number will be small compared to immediate germinations secured from a given amount of fuzz.

(2) The viability of seed declined rapidly in the first 3 months period in all treatments in this test.

(3) With 25 gms. of calcium chloride per 1000 cc. space, the use of carbon dioxide gave almost 100 per cent more germinations than were secured with air (see Figs. 5 and 6), while the use of oxygen gave only 42 per cent as many germinations as with the use of air (see Fig. 6).

(4) Carbon dioxide without the drying agent ($CaCl_2$) gave no germinations after 3 months (see Fig. 6).

(5) Air drying of seed at 32-35° C. in an electric oven gave fairly good germinations at 3 months (426 per can), but failed to keep viability for a longer period (see Fig. 2).

(6) Using calcium chloride and carbon dioxide uniformly and varying the temperature from 75° F. to 31° F. gave pronounced results in favor of 31° F., the lowest temperature tried (see Fig. 3).

At 9 months temperature of 75° F. gave only 1 germination per can. But with each decrease in temperature there was an increase in germination until at 31° F. there was an average of 535 germinations.

(7) Varying the amount of calcium chloride from 9 gms. to 60 gms. per 1000 cc. space in storage cans gave results in favor of the smallest amount of calcium chloride (see Fig. 4). In germinating air-dried seed that had been stored for 9 months at 68° F., the seed having 9 gms. of $CaCl_2$ per 1000 cc. space gave

307 germinations (C-1) compared with 11 germinations* (C-2) obtained from seed stored with 25 gms. $CaCl_2$ per 1000 cc. space. The use of 60 gms. of calcium chloride ($CaCl_2$) yielded only one germination. We would therefore conclude that it is possible to have too much calcium chloride as well as too little.

From the results obtained in this experimental work, the following procedure seems to be the best way to preserve cane seed:

(1) Air dry the tassel promptly. In case of damp, cloudy weather the tassels may be dried by calcium chloride placed with the tassels in large carbide tins. These tins should be inspected daily and the tassels shaken out to insure good air circulation.

(2) When the fuzz is crisp dry and shatters easily, it should be stripped from the tassel and placed in cans. Carbon dioxide should be introduced to displace the air as completely as possible.

(3) Use calcium chloride at the rate of 9 gms. per 1000 cc. space for the final storage of dry seed. This amounts to ¾ pound per large carbide can. It is preferable to divide this amount into 4 or 5 small cans covered with cheesecloth. These cans are distributed throughout the fuzz mass in the large can.

(4) After a second introduction of CO_2, seal the cans air tight with sealing wax or paraffine and label.

(5) Place the cans in cold storage at 31° F. immediately.

It is very essential that the drying and canning operations take place promptly after the tassel has been cut, as a delay of over 7 days means a high percentage of loss. Delays over 7 days probably mean a loss of viability of 10 per cent of the remainder per day. Good material will give almost no germination after being held for 3 weeks in the drying house.

LITERATURE CITED

(1) Smith, Overton, Gilbert and others. 1924. A Text Book of General Botany. p. 315 MacMillan Company.

(2) Peirce, G. L. 1903. Plant Physiology. pp. 9-10. Henry Holt and Company.

(3) Kinman, C. F., and McClelland, T. B. 1916. Porto Rico Agricultural Experiment Station Bulletin 20.

(4) Cooke, D. A. 1926. The Preservation of Cane Seed. Reports of the Association of Hawaiian Sugar Technologists. pp. 63-65.

* Germinations obtained from the other lots receiving the same specific treatment as C-2 agree very closely, i.e., B-2=14.3; and A-1=31.6 germinations (Table III—summary).

Notes on Irrigation Control and Investigations

WAIMANALO SUGAR COMPANY

By H. R. Shaw

Plantation Irrigation and Equipment

The plantation of the Waimanalo Sugar Company is entirely dependent on surface run-off for its irrigation water. By utilizing the water from the Waimanalo and Maunawili valleys, a maximum of ten million gallons per day and an average of eight million gallons per day is available to the plantation.

Ditches: Three main irrigation ditches carry the water to the plantation proper. The Waimanalo-Maunawili ditch, with its source in the upper levels of the Maunawili valley, comes through an 800-foot tunnel to Waimanalo valley, and delivers from two to three million gallons per day to the upper fields of the plantation.

The Kailua pump ditch originates in the Kailua swamp, where the run-off from the Maunawili valley accumulates. The swamp covers approximately 500 acres and has a storage capacity of one billion gallons. A canal has been dug into the swamp, and the water is pumped to a ditch running through the center of the plantation. The daily delivery is about 4 million gallons.

The Lagoon ditch, delivering 2 million gallons per day, is supplied from another swamp on the lower levels of the plantation, and is used for the irrigation of the *makai* fields.

Pumps: The Kailua pump unit consists of two 175 h. p. Westinghouse electric motors, and is capable of pumping 7¾ million gallons per day against an 180-foot head. The pumping range in the swamp is from four feet above to four feet below sea level. The water is of very good quality; the maximum salt content to date being 30 grains NaCl per gallon, and the average being 6 grains NaCl per gallon.

The Lagoon pump unit is capable of pumping 4¼ million gallons per day against an 80-foot head, and has one 75 h. p. Fairbanks-Morse Diesel and one 100 h. p. General Electric motor.

Field Layout: The plantation fields are laid out for the usual Hawaiian furrow system of irrigation. The watercourses are 30 feet wide, the length depending on the contour of the ground. The furrows are 5 feet wide.

Irrigation: An adaptation of the Hawaiian furrow system is used at Waimanalo. The irrigator, as he works down the watercourse, irrigates the odd-numbered lines only; upon reaching the bottom of the watercourse, he works up irrigating the even-numbered furrows*. This method shows an advantage of over double the number of acres per man day and an appreciable saving of water

* *Hawaiian Planters' Record,* Vol. XXXI, 1927. page 151.

over the usual one line system. Other plantations in the Islands have used this system in the past; Hawaiian Commercial and Sugar Company has irrigated parts of their plantation in this way for over ten years, and has adopted it as their standard plantation practice within the past two years.

Surveys: Gross area is used in all field surveys at Waimanalo. The government roads and three main irrigation canals are excluded, but all plantation roads and field ditches are included in the field area. In experimental level ditch plots, the level ditch is included in the area survey; in experimental watercourse plots, the level ditch is excluded, the area being taken from the center of the watercourse to the center of watercourse and from the center of the level ditch bank to level ditch bank.

Ditch Lining: The main ditch seepage ranges from 9 to 25 per cent per mile. Good results have been gained from ditch lining, and the plantation expects to complete the lining of all main ditches as rapidly as possible. About four miles of ditch lining have been completed at present.

The Waimanalo-Maunawili ditch has a base width of 24 inches and a depth of 18 inches on a 6-inch slope. The bottom is two-inch solid concrete, and the sides are four-inch rock and concrete. The lining costs $1.00 per foot, of which 75 per cent is for labor and 25 per cent for material, hauling, and overhead.

Ditch lining seems to be the best method of increasing water for the fields at Waimanalo. It is estimated that a saving of from one to two million gallons per day will be made by lining the Maunawili ditch. A proposed ditch running 180 feet below the present Maunawili ditch would catch the upper ditch seepage and overflow, springs, and lower streams, and would deliver 1½ to 2 million gallons per day more. Waimanalo is handicapped by its lack of reservoirs, and would nearly double its present water supply if it were possible to store freshet water during the rainy season.

Water Measurements

History: Water measurements at Waimanalo were started in 1923 as a cooperative movement between the Experiment Station and the plantation. The work was under the direction of G. R. Stewart, and under the immediate supervision of William Weinrich, until 1924, when T. K. Beveridge took charge. Waimanalo was one of the first plantations to use the Lyman meter, the first installation being made in 1924. The entire plantation of 2500 acres (33 fields) was put under meter measurement in 1926.

Equipment: The main measuring stations are standard rectangular weirs. The plantation has three 3-foot, one 4-foot, and one 5-foot weirs equipped with two Friez and three Gurley flow recorders. The weirs have a side contraction equal to the width of the weir, bottom contraction equal to or greater than the width of the weir, and a stilling pond equal to 10 times the width of the weir.

Mr. Beveridge recommends the Gurley recorder with a weight-driven clock (Catalogue No. 636, price $145.00) rather than the spring-driven clock (Catalogue No. 633), which has frequent stoppages and has the entire weight of the horizontal beam on the clock.

The field stations, equipped with Lyman meters, are installed at the junction of the main ditch and the field ditch. The installation at this point gives a higher water rate to the individual fields than is actually the case, but it makes it possible to establish a water balance of field consumption against the total supply. There are 32 concrete installations with a depressed basin 24 inches long at the orifice. The bottom of the orifice is flush to the base board of the depressed basin (in other words, there is no bottom contraction on the orifice gate). This feature eliminates deposits of silt in the basin, does not raise the water in the ditch to a high level, eliminates much inaccuracy of the meter with fluctuating heads, and of the orifice not being submerged at low heads. With the depressed basin it is possible to use a larger orifice and thus eliminate the danger of water backing up in the ditch.

Meters: Twenty-four Lyman meters, all rated for a one square-foot orifice, are used in the field installations. The interchangeable orifice gates have seven different sizes of orifice, ranging from ½ square foot to 4½ square feet.

The plantation has had excellent results from the Lyman meter, and favors them over any other measuring device with the exception of the weir. Mr. Beveridge says: "As far as the Lyman meter is concerned, I do not think that there is a better water measuring device on the market that can compare with it for price and practicability. It is easily handled (and this is an important feature for field use), is cheap, and is as accurate as any other machine that is made. In order to be accurate, the Lyman meter has to be checked carefully. This can very easily be done with the proper equipment."

Meter Costs: The cost of the concrete meter installation in use at Waimanalo is from $12.00 to $15.00 each. This is no more expensive than if made of redwood, and the life is indefinite as compared with a life of from three to five years for wooden structures.

The cost of the Waimanalo installation is as follows:

Installation of 30 concrete meter boxes at $12.00	$ 360.00
Cost of 24 Lyman meters at $50.00	1,200.00
Cost of orifices	100.00
Total cost	1,660.00
Total area of plantation	2,500 acres
Cost per acre	0.664
Cost of meter and installation for 5 years	70.00
Cost of supervision and care for 5 years	113.40
Total cost for 5 years	183.40
Cost per year (estimating life of Lyman meter at 5 years)	36.68

Meter Checking: All meters are checked at the first of the irrigation season against a three-foot rectangular weir, and thereafter throughout the season as is necessary. In checking, the meter is installed directly below the weir, and the efficiency of the meter rated. The efficiency ranges from 65 to 110 per cent, taking the weir reading as 100 per cent. The average accuracy of the meter is about 85 per cent. Corrections based on the accuracy of the meter are made on all field meter readings.

One meter is checked monthly against the weir, and is then used to check the meters in the field. The field meter is run for a given period, and the rate of flow noted; the check meter is then substituted and run in the installation for the same period of time.

Reports: One man handles all of the field meter readings and part of the office work for the plantation. The agriculturist compiles all other irrigation data. The following forms are used for compiling irrigation data for Waimanalo:

WAIMANALO SUGAR COMPANY

Daily Irrigation Report

Report No.................... Date..19......

No. of Men Irrigating..

Field No.	Round No.	DITCHES						Field No.	Round No.	DITCHES					
		Maunawili	Kailua	Pump	Tai Lee	W. G.	B. P.			Maunawili	Kailua	Pump	Tai Lee	W. G.	B. P.

Form I

WAIMANALO SUGAR COMPANY
IRRIGATION METER RECORDS

Box No.__________ Ditch____________

Date________________ Meter No.__________

ORIFICE	READING	
Finish No.______	________	
Start No.______	________	________
Finish No.______	________	
Start No.______	________	________
Finish No.______	________	
Start No.______	________	________
Finish No.______	________	
Start No.______	________	________

Total Acre Feet (Gross) ________

Correction (Plus or Minus) ________

Total Acre Feet (Net) ________

____

Remarks:

Nº 5594

Form II

1. Section Lunas' Daily Report (Form I).
   Filled daily by section lunas. Entered and checked against man-day summary sheet (see '6' below).
2. Daily Meter Report (Form II).
   Filled by boy in charge of meter readings. Entered in Round Report ('4') and Field Segregation ('5').
3. Monthly Irrigation Distribution (Form III).
   Taken from Section Lunas' Daily Report ('1') and from total gallons per ditch.
4. Round Report (Form IV).
   Summary of plantation irrigation to fields by rounds.
5. Field Segregation (Form V).
   Shows distribution of men and water to each field. Acts as balance sheet for plantation irrigation.
6. Man Day Summary Sheet (Form VI).
   Shows distribution of men by month. Checks with Section Lunas' Report ('1').

7. **Field Weir Record (Form VII).**
For use in experimental plots with water measured by small weirs without flow recorders.

FORM III

IRRIGATION DISTRIBUTION

Crop................ Month................

PLANT

Field	No. of Men	Maunawili-Waimanalo Water	No. of Men	Kailua Water	No. of Men	Lagoon Water

RATOON

Field	No. of Men	Maunawili-Waimanalo Water	No. of Men	Kailua Water	No. of Men	Lagoon Water

FORM IV

WAIMANALO SUGAR COMPANY

Round Report No. ....

Field No.	Round No.	Total Acres	Total for Round Gallons	Total for Round Man Days	Age of Cane in Months	per M.D.	per Ac.	Acs. per M.D.	Ac. In. per M.D.	Ac. In. per Acre

FORM V

FIELD SEGREGATION

Field No................ Crop.................
Area.................... Ditch................

Date	Acre Feet Upper Box	Acre Feet Lower Box	Total Acre Feet	Total Gallons per Day	No. of Men	Gallons per Man Day

FORM VI

MAN-DAY SUMMARY SHEET

Month: ....

Date	1 R	3 R	4 R	6AB SR	6C SR	8 R	9 R	10 R	11 P	11 R	13 R	14 P	14 R	15 P	15 R	19 P	20 R	Etc.	Total No. of Men
1																			
2																			
3																			

Special Irrigation Experiments: Interval tests in two fields have been repeated since 1923 with the following results:

D 1135 Field No. 4 Harvested: March, 1925

Treatment	T. C. P. A.	T. S. P. A.	Gals. per Acre	T. S. per Ac. In.
Weekly	55.45	4.076	1,718,577	0.061
Plantation	47.73	3.079	579,600	0.140

H 109 Field No. 15 Harvested: September, 1925

Treatment	T. C. P. A.	T. S. P. A.	Gals. per Acre	T. S. per Ac. In.
Weekly	54.60	6.91	2,132,132	0.088
Monthly	54.93	6.24	563,174	0.300
Plantation	51.41	5.78	502,892	0.312

H 109 Field No. 15 Harvested: January, 1927

Treatment	T. C. P. A.	T. S. P. A.	Gals. per Acre	T. S. per Ac. In.
Weekly	50.75	5.14	1,842,190	0.076
Monthly	49.22	4.38	912,045	0.128
Plantation	46.57	4.65	773,050	0.170

Waimanalo Sugar Company

IRRIGATION RECORD

Field No. .... Date ....19.

Irrigation No............... No. of Men...............

Time	Staff Reading	Time	Staff Reading	Time	Staff Reading	Time	Staff Reading
:00..	....	.. :00..	....	.. :00..	....	.. :00..	....
:05..	....	.. :05..	....	.. :05..	....	.. :05..	....
:10..	....	.. :10..	....	.. :10..	....	.. :10..	....
:15..	....	.. :15..	....	.. :15..	....	.. :15..	....
:20..	....	.. :20..	....	.. :20..	....	.. :20..	....
:25..	....	.. :25..	....	.. :25..	....	.. :25..	....
:30..	....	.. :30..	....	.. :30..	....	.. :30..	....
:35..	....	.. :35..	....	.. :35..	....	.. :35..	....
:40..	....	.. :40..	....	.. :40..	....	.. :40..	....
:45..	....	.. :45..	....	.. :45..	....	.. :45..	....
:50..	....	.. :50..	....	.. :50..	....	.. :50..	....
:55..	....	.. :55..	....	.. :55..	....	.. :55..	....
:00..	....	.. :00..	....	.. :00..	....	.. :00..	....
:05..	....	.. :05..	....	.. :05..	....	.. :05..	....
:10..	....	.. :10..	....	.. :10..	....	.. :10..	....
:15..	....	.. :15..	....	.. :15..	....	.. :15..	....
:20..	....	.. :20..	....	.. :20..	....	.. :20..	....
:25..	....	.. :25..	....	.. :25..	....	.. :25..	....
:30..	....	.. :30..	....	.. :30..	....	.. :30..	....
:35..	....	.. :35..	....	.. :35..	....	.. :35..	....
:40..	....	.. :40..	....	.. :40..	....	.. :40..	....
:45..	....	.. :45..	....	.. :45..	....	.. :45..	....
:50..	....	.. :50..	....	.. :50..	....	.. :50..	....
:55..	....	.. :55..	....	.. :55..	....	.. :55..	....

Form VII

This test is to be made again in a more representative field during the next crop.

In addition to the above experiment, a hilling-up versus non-hilling-up irrigation experiment and a five-foot line versus four and one-half-foot line experiment are to be put in this year. One field is to have complete meter control on level ditches in order to see if it is practicable to extend the present system of meter control.

Economy by Meter Control: The plantation management has found that meter control of their fields has given them a decided saving in water and in man power. They estimate a saving of 20 per cent water and 50 per cent labor since their control system has been in practice. The use of meters has a psychological effect

on the irrigators, and the knowledge that the plantation management is able to keep a check on their work causes them to cover a greater area and give a more efficient irrigation to the fields. The following table shows the increase in efficiency during the first four irrigations after the meter system was installed:

ECONOMY IN MAN POWER

Acres per Man Day

RATOON FIELDS

	No. 1	No. 2	No. 3	No. 4
	0.405	1.208	1.255	1.144
	0.368	1.131	1.176	0.980
	0.968	0.801	1.935	1.786
	0.495	0.737	1.129	1.146
	1.026	Inc.	0.910	Inc.
	0.733	1.430	Inc.	0.715
	1.021	0.781	1.021	1.021
	0.473	1.268	1.381	1.146
	0.360	Inc.	0.785	1.200
	0.451	1.613	Inc.	1.173
	0.418	Inc.	0.885	1.150
	0.396	0.772	1.128	1.419
	0.831	0.782	1.064	Inc.
	0.542	0.515	1.034	1.190
Avg.	0.606	1.003	1.143	1.197

PLANT FIELDS

	No. 1	No. 2	No. 3	No. 4
	0.510	Inc.	0.962	0.984
	0.293	0.475	0.475	0.366
	0.332	1.307	0.817	Inc.
	0.484	0.846	1.471	0.940
	1.579	1.378	Inc.	1.579
	0.775	0.948	1.478	Inc.
	0.405	0.460	1.006	1.086
Avg.	0.625	0.902	1.035	0.991

ECONOMY IN WATER

Acre Inches per Acre

	No. 1	No. 2	No. 3	No. 4
	13.97	5.20	4.77	6.00
	10.35	3.55	4.69	2.83
	9.32	7.61	2.43	....
	7.40	7.18	5.70	....
	5.10	2.61	....	....
	3.15	6.20	....	4.97
	7.25	5.43	....	5.14
	14.25	5.56	....	....
	4.25	2.98	....	2.40
	8.66	3.76	....	4.03
	10.06	7.38	6.34	4.55
	3.56	7.34	5.58	3.99
	8.68	7.49	....	5.38
	7.47	3.24	1.96	2.87
	11.95	3.86	3.13	3.33
	8.20	9.92	4.81	4.79
	5.98	3.79	4.45	4.63
Average	8.21	5.48	4.39	4.22

Waimanalo has found a considerable saving of water in connection with their short cropping program. Not only do they obtain a greater yield of sugar per acre from cane 17 or 18 months old, but the tons sugar per acre-inch of water is much higher than on a full 24-month old crop. The following figures show the advantage of short crops over long crops as far as irrigation is concerned:

Type	Age	Tons Sugar per Ac. In.
Ratoon	17	0.126
"	18	0.180
"	19	0.094
"	16	0.117
"	19	0.177
"	22	0.138
"	20	0.099
"	21	0.063
Plant and Ratoon	20	0.093
" " "	21	0.078
" " "	24	0.075

Notes on Irrigation Control and Investigations

OAHU SUGAR COMPANY

By H. R. Shaw

Plantation Irrigation Equipment

Supply: Both artesian and mountain water comprise the irrigation supply of the plantation. Ten main pumping units with a capacity of 94 million gallons per day handle the artesian supply with 4 smaller booster units to pump the water to higher levels. Two additional pumps are used for pumping from streams.

Mountain water is obtained from the Waiahole conduit, which furnishes nearly 75 per cent of the total from that source and from 3 flood water ditches on the Waipahu side of the island. The total flow of mountain water for 1927 was:

Waiahole	13,547.0	M. G.
Waiawa	152.8	"
Kipapa	3,133.1	"
Waikakalaua	1,414.8	"
Total	18,247.7	"

The total amount of artesian water pumped in 1927 was 14,499.053 M. G., of which 421.707 M. G. was rehandled by the booster units.

Field Layout: The plantation is irrigated by means of the usual Hawaiian furrow system, one line irrigated at a time being the standard practice. The watercourses are from 30 to 35 feet wide, the length varying with the contour.

Survey: All fields are gross acreage, and the boundary is taken from a point three feet out from the actual cane boundary. Watercourse surveys are from center of watercourse to center of watercourse and from level ditch bank to level ditch bank.

Ditch Lining: Waipahu has completely lined nearly all of the main supply canals. The lining is of one square foot slabs of blue lava rock with ordinary cement mortaring. This type of lining is more substantial than concrete, costs no more, and has a longer life. At present, the plantation has completed 24.53 miles of stone ditching, not including the Waiahole ditch, which is concrete lined.

Water Measurements

Control: Water measurements on the plantation are controlled by the engineering department, which is in charge of all installations, maintenance of meters, and actual water measurements as well as of special tests on ditch and reservoir seepage and on field measurements.

The staff includes an engineer in charge, two clerks who divide their time between office work and field meter supervision, and two field meter readers who take the meter readings, change orifice gates, and have general care of the meters.

Meteorological Station: A complete meteorological station is maintained by the plantation engineering department for general weather observation and for use in connection with irrigation investigations. Velocity and direction of wind, hours sunshine, soil and air temperatures, and humidity are recorded daily. Fifteen official rain gauge stations are maintained on different sections of the plantation.

An evaporation station, used in connection with studies on reservoir losses, has been recently installed. The evaporation pan of 24-gauge galvanized iron is four feet in diameter. Evaporation loss from the free water surface is recorded daily. Records of temperature, humidity and rainfall at the station are also kept.

Equipment: Every pump unit is equipped with a Venturi meter for determining the daily discharge, as well as with a rectangular weir for checking the flow. Three weirs are installed in the field, but are used only for checking meters. None of these weirs have flow recorders. Nine rectangular weirs are installed on the Waiahole ditch and supply streams. These installations have Gurley recorders, which register the gauge height every half hour instead of the more common graphic flow recorder. These recorders give a continuous flow record for a month at a time, and require little attention.

Thirty-seven Reliance and 63 Lyman type of irrigation meters are used in the field installations. Early Lyman installations made no provision for a constantly submerged orifice, and the resulting inaccuracies of the meter readings caused the plantation management to prefer the Reliance type. At the present time, however, the Lyman installations are of the box type with a depressed 'V' basin. The box is of redwood lined with galvanized iron, which not only gives the installation a longer life, but by retaining the water in the box prevents the wind from revolving the meter propeller when not in use. This wind action has often been a cause of inaccuracy unless readings are taken immediately before and after each irrigation. The results gained since using the improved installation have been such as to encourage the use of the Lyman meter.

Mr. H. Olstad, in charge of meter installations, says: "As far as relative accuracy is concerned there is no difference between the Reliance and Lyman meters. With a permanent installation in a ditch with fairly constant flow, I

consider the Reliance preferable. However, the meter has its limitations in handling a fluctuating flow and in lack of ready portability."

Records: A rather elaborate and extensive card index system of records is used in connection with water measurements.

Forms I and II show the location of each meter installation by fields and by installation numbers.

Forms III and IV give the results of checking tests for each meter.

Forms V, VI and VII give the detailed report on the checking tests conducted for each type of meter and for the weir installations, while Form VIII is a summary of all the checking tests.

FORM I

FIELD NO.______

BOX	INSTALLED	LOCATION

FORM II

INDEX FOR BOXES

BOX__________

LOCATION	TYPE	INSTALLED	REMARKS

FORM III

Index for Reliance Meter

Reliance Meter: ________ *Factory No.* ______ *Type:* ______

Year: ____ *Size:* ________ *Meter Rec'd:* ______

LOCATION	Month	Date	Test	REMARKS

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FORM IV

INDEX FOR LYMAN METER

LYMAN METER ______ MODEL ______ ORIFICE ______ SQ. FT.

FACTORY NO. ______ C ______ ONE REV. ______ CU. FT.

YEAR: ______ METER REC'D. ______

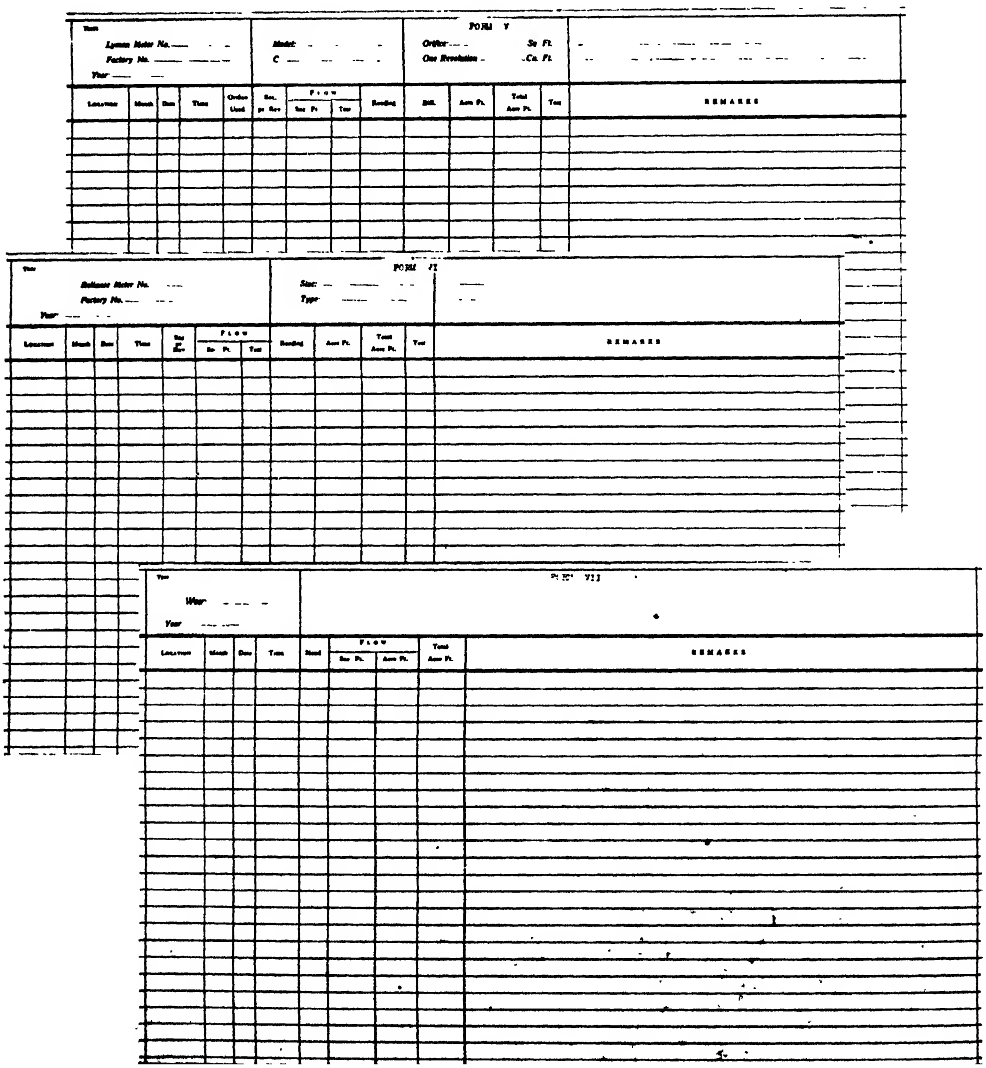
LOCATION	MONTH	DATE	TEST	REMARKS

ADVERTISER 187744

Form IX gives the results of each irrigation as recorded at the installation, and Form X is a complete history of the irrigation to each field under measurement as compiled from the results of all installations in the field.

Form XI is a report on water measurements to experimental plots, compiled for the convenience of the agriculturist.

Form XII is a final summary at the end of the crop irrigation. It should be noted that the term "Interval Days" refers to the length of time from the start of one irrigation to the start of the next, including Sundays, holidays, and all other non-irrigation days, rather than the usual meaning of "number of days *between* irrigations." A "round period" at Waipahu is considered as from the start of one irrigation to the start of the next, regardless of the actual number of irrigation days during the round. For instance, the sixth irrigation in Field No. 48 began on December 4, 1927, and ended March 19, 1928, a total period of 106 days; but there were only 31 actual irrigation days during this period.



FORM VIII

Year

Location	Month	Date	Time	Weir		Reliance Meter					Lyman Meter					Remarks
				Flow Sec Ft	Total Acre Ft	No.	Flow		Total		No.	Flow		Total		
							Second Ft	Test	Acre Ft	Test		Second Ft.	Test	Acre Ft	Test	

FORM IX

Box No.

Year.

LOCATION

Area

Month	Date	Meter	Cu. Ft. per Rev	Meter Orifice	Time	Orifice Used	Reading	Diff.	Acre Ft	Total		Grand Total		Inches per Acre	Men Irrigating	Remarks
										Acre Ft.	Gallons	Acre Ft	Gallons			

FORM X

Field No

Year

LOCATION

Area

Year	Month	Date	Total Acre Ft	Total Mill Gals.	Grand Total Acre Ft	Grand Total Mill Gals.	Inches per Acre	Mill Gals. per Acre	Men Irrigating	Time Required	Man Hours Acre	Man Hours Gallons	Remarks

FORM XI

OAHU SUGAR COMPANY, LTD.

IRRIGATION METER RECORDS

Date . . .

Field No. *Box No.*. . . *Round No.* *Meter No.* *Cane* . *Crop*. . . . .

	TIME		READING		ORIF.	DIFF.	AC. FT.	
	Start	Finish	Start	Finish				

Total Ac. Ft.. . *Total Man Hours* . . . .

	Course No.	Start	Finish	No. of Hrs. Mins.	Course No.	Start	Finish	No. of Hrs. Mins.

FORM XII

RECORD OF MEASURED IRRIGATION WATER IN FIELD NO. 48 (166.82 ACRES, ELEVATION 400'-500') FOR CROP 1928—H 109—SECOND RATOON

Rounds	Beginning	Ending	Int. days	Acre feet	Million gallons	Inches per acre per round	Av. inches per acre per day	Mill. gals. per acre	Total rainfall in inches	No. of irrigation days	No. of man days	Man day acre	Man day million gallons
Pre-Irrigation	April 29/26	May 31/26	33	......	......	....	...	....	.78	..	...	...	....
1	June 1	June 29	29	43.766	14.261	3.15	.11	.086	5.23	23	242	.69	.059
2	June 30	Aug. 10	42	64.715	21.088	4.66	.11	.126	2.52	37	348	.48	.061
3	Aug. 11	Sept. 14	35	69.630	22.689	5.01	.14	.136	2.22	30	297	.56	.076
4	Sept. 15	Oct. 16	32	78.190	25.478	5.62	.18	.153	1.62	28	287	.58	.089
5	Oct. 17	Dec. 3	48	77.012	25.094	5.54	.12	.150	3.47	32	278	.60	.090
6	Dec. 4/27	Mar. 19/27	106	143.968	46.912	10.36	.10	.281	11.57	31	319	.52	.147
7	Mar. 20	May 11	53	116.537	37.974	8.38	.16	.228	9.66	19	214	.78	.177
8	May 12	June 15	35	115.269	37.561	8.29	.24	.225	5.29	21	229	.73	.164
9	June 16	July 1	16	96.410	31.415	6.94	.43	.188	0.47	15	171	.98	.184
10	July 2	July 25	24	107.119	34.905	7.70	.32	.209	1.03	19	211	.79	.165
11	July 26	Aug. 19	25	132.067	43.034	9.50	.38	.258	0.65	23	211	.79	.204
12	Aug. 20	Sept. 15	27	143.485	46.755	10.32	.38	.280	0.98	23	202	.83	.231
13	Sept. 16	Oct. 22	37	127.285	41.476	9.16	.25	.249	1.83	31	200	.83	.207
Ripening period	Oct. 23/28	Mar. 4/28	134	......	......	....	...	....	31.84	..	...	...	....
Harvesting period	Mar. 5	Mar. 19	15	......	......	....	...	....	.24	..	...	...	....
Total				1315.453	428.642	94.63	2.92	2.569	79.40	332	3209	9.16	1.854
Average				101.189	32.972	7.28	.22	.198	6.11	26	247	.70	.143
Maximum				143.968	46.912	10.36	.43	.281	31.84	37	348	.98	.231
Minimum				43.766	14.261	3.15	.10	.086	0.47	15	171	.48	.059

Form XIII is a final crop summary for each field under measurement.

FORM XIII

Field 41
Elevation 550′ to 650′
Cultivation period, March 21, 1925-April 1, 1927—742 days

Area in acres—171.97.
Variety of cane—D 1135.
Class of cane—New plant and long ratoon.
No. of rounds—18.
Irrigation water delivered at top of field:
  Acre feet—1271.29;
  Million gallons—414.251;
  Inches per acre—88.71;
  Million gallons per acre—2.409;
Total rainfall in inches—69.20.
No. of irrigation days—383.
No. of man days—4145.
Man day acre—.78.
Man day—million gallons—.104.
Tons cane—15961.
Tons cane per acre—92.81.
Tons sugar—1728.
Tons sugar per acre—10.05.
Million gallons per ton cane—.02595.
Million gallons per ton sugar—.23973.

Irrigation Investigations

Policy: In speaking of the plantation policy on irrigation investigations, E. W. Greene, manager, remarked: "There are two general procedures which may be followed in experimental work of this kind. One method is to put in an extensive metering system covering every field on the plantation, to gather a mass of data on general irrigation practice, and to attempt to apply these data to field conditions. The second method, which is used on this plantation, is to choose a few typical fields representative of various field conditions, and to obtain complete and accurate data on them. We feel that our first task is to determine what is being accomplished by the present practice and what mistakes are being made before we attempt to say what should be done in the future."

Purpose: The problems to be solved by irrigation investigation have been divided into four main projects:

1. Field water measurement.
2. Determination of seepage losses in reservoirs.
3. Determination of seepage losses in supply straight and level ditches.
4. Agricultural experiments.

The first three of these projects are being investigated by the plantation engineering department, the fourth is handled by the plantation agriculturist.

Field Measurements

Twelve fields, comprising about 1800 acres, are under actual measurement. The fields are located in different sections of the plantation, and represent as far as possible the soil type, contour, and field conditions of the particular section.

If results on present investigations warrant further installations, it is planned to expand the measurements to each newly plowed field after every crop season. In this way the measurements will be gradually extended to cover the entire plantation.

One of the most interesting figures brought out by the field measurements is the variation of the average acre-inches per acre per day throughout the growth season. The increase of water application during the better growth months is illustrated in Field No. 48, 1928 crop:

Month	Average acre-inches per acre per day
Crop started June	0.11
July	0.11
August	0.14
September	0.18
October-November	0.12
December-January-February	0.10
March-April	0.16
May	0.24
June	0.43
July	0.32
August	0.38
September	0.38
October	0.25

Determination of Seepage Losses in Reservoirs

Perhaps the most interesting and valuable experiments so far made by the plantation are the investigation of reservoir seepage losses, and methods of treatment to minimize these losses. The work is still in the experimental stage, and no definite decision as to the most effective and economical method of lessening reservoir seepage can be made as yet.

The experiments on reservoir seepage have clearly demonstrated to the plantation management:

1. That a surprisingly large amount of water is lost while standing in reservoirs.

2. That it is not advisable to store night water in reservoirs when it is at all possible to get the water to the fields during the day.

3. That the practice of filling all reservoirs on Saturday night and allowing the water to stand until Monday morning is highly wasteful.

Determination of Seepage Losses in Main Supply, Straight and Level Ditches

Detailed and accurate investigations have been made of the seepage losses in main supply, straight and level ditches. The results are interesting, not only in showing how great a proportion of irrigation water is lost before it reaches the cane, but in making it possible to show, theoretically, the probable losses of water during a crop season.

Loss in Main Supply Ditches:

Location	Soil type	Per cent loss per 1000 ft.	Per cent loss per Mile
Waiawa	Medium	1.67	8.82
Honouliuli	Medium	1.92	10.14
Honouliuli	Medium	2.50	13.20
Waipio	Very loose	21.00	110.88

Loss in Straight Ditches: These data show the decreasing loss in straight ditch seepage as the soil becomes saturated with water. The test was started on a dry earth ditch, medium soil, slope 0.035:

Preceding continuous run	Per cent loss per 1000 ft.	Per cent loss per Mile
Dry ditch	3.10	16.37
24 hours	2.54	13.41
48 hours	2.34	12.35
72 hours	1.80	9.50
96 hours	1.65	8.71
360 hours	1.50	7.92
59 days, ordinary usage with 2.5 to 3.0 million gallons flow per day	1.65	8.71

Loss in Level Ditches:

Soil type	Ditch	Per cent loss per 1000 ft.	Per cent loss per Mile
Loose on sidehill	Dry	4.87	25.71
	Saturated	2.63	13.89
Medium	Dry	2.40	12.67
	Saturated	1.60	8.45

Calculation of Probable Losses in Ditches: The preceding data have led to some interesting studies in the probable losses in a field before the water reaches the cane. Although the figures are theoretical calculations, they are based on sufficient experimental and verified data to indicate a close approach to actual conditions.

The following calculations are based on data from Field No. 42, 1927 crop:

Area—228.74 acres.
Irrigation days—518.
Rounds—15.
Average days per round—34.5.
Total water applied—774.184 million gallons.
Million gallons per day—1.495.
Length straight ditches—13,175 feet:
  Per acre—57.6 feet.
  Average length used—3294 feet per irrigation day.
Length level ditches—45,895 feet:
  Per acre—200.7 feet.
  Average length used—1330 feet per irrigation day.

Losses in Straight Ditches

Losses in straight ditches—13,175 feet:

Average daily in use $\frac{1}{4} \times 13175 = 3294$ feet.
Loss per 1000 ft., 1.65%.

Total daily loss $\dfrac{3.294 \times 1.65 \times 1.495}{100} = 0.081$ million gallons.

1927 Crop total loss, 40.958 million gallons = 5.3 per cent.

Losses in Level Ditches

Losses in level ditches—45,895 feet:

Average amount water per day, $1.495 - 0.081 = 1.414$ million gallons.
Loss per 1000 ft. = 2.6%.

$\dfrac{45895}{34.5} = 1330$ ft. average in use per day.

Loss per day $\dfrac{1.330 \times 2.6 \times 1.414}{100} = 0.050$ million gallons.

1927 crop, total loss 29.900 million gallons = 4.1%.
Total loss in all ditches per day, 0.131 million gallons.
Total loss in all ditches, 1927 crop, 70.858 million gallons = 9.2 per cent.

Agricultural Experiments

Some highly valuable and interesting investigations on irrigation in relation to the growth of the crop and the moisture content of the soil are being conducted by the agriculturist, William Wolters. The studies, which cover a period of over three years, are especially concerned with the optimum soil moisture content required for maximum growth.

Experiments on soil moisture capacity are being conducted in four fields of widely varying soil types. The per cent moisture in the first four feet of soil, the linear cane growth, the rainfall, and the temperature are correlated for weekly

periods during the entire crop season. Detailed graphs showing the entire history of the crop based on the foregoing data have been prepared.

These graphs show clearly some instructive points in the relation of irrigation to the moisture content of the soil and the growth of the crop. Although the work is still in the experimental stages, the following indications are plainly illustrated in the soil types studied:

1. That there is a decided response to cane growth after an irrigation. This response is most marked during the first week after the irrigation. After the first week there is a consistent decline in the rapidity of growth, although the decline may sometimes be rapid and at other times gradual. The greatest drop is during the second week after irrigation, and is most pronounced in the summer months.

2. That there is a close correlation between cane growth, water application and temperature.

3. That in fairly porous soils, a greater response of cane growth is obtained from frequent light irrigations than from heavier applications at longer intervals.

4. That tight, rather impervious soils require twice the amount of water per application, but that the interval between irrigations may be much longer than in loose, porous soils.

5. That there is a surprising difference between the percolation rates of tight and of loose soils.

6. That most of the water in tight soils is retained in the first and second feet; in loose soils, most of the water is retained in the third foot.

7. That although tight soils require nearly one-third less irrigation than loose soils, the applications to tight soils must be heavier, and that they will use more total water than the porous soils. This might be explained by the fact that in tight soils there is more evaporation loss from free water in the surface, and that less water is utilized by the cane roots. In porous soils, the percolation is greater, but capillary action brings the water to the third foot and within reach of the plant.

8. Moderate to heavy rains will influence growth and the response at times is equal to that from an irrigation. Climatic and seasonal influences have a noticeable effect on growth.

9. On a number of occasions, growth is meager in spite of favorable moisture and temperature. The limiting factor in this case is probably the hours of sunshine available.

10. Excessive wind movement has a decided effect on cane growth. This is shown in a field exposed to wind action where the growth for August, 1925 (generally the month of greatest growth), took a drop equal to that of winter growth.

11. That a combination of high wind velocity, low relative humidity, high temperature, and bright sunshine has a decided effect in drying the field and in checking cane growth.

Moisture Increase and Decrease After Irrigation

Special attention has been paid to the fluctuation of the soil moisture content immediately following an irrigation. Special soil samples are taken the day before and two days after an irrigation. Samples are taken every seven days thereafter to determine the decrease in moisture. Such decreases are due to:

1. Evaporation.
2. Percolation.
3. Utilization of water by the cane plant.

The purpose of the studies is to determine the amount of water necessary to raise the soil moisture content to the desired point, the daily increase in moisture after an irrigation, and in what proportion the decrease is due to each of the three factors of evaporation, percolation and utilization by the plant.

It has been found that:

1. It is difficult, with normal irrigations, to increase the soil moisture content to an optimum when the soil is very dry. Cases show that in winter months, a greater amount of water is required to raise the moisture content one per cent than in June. This condition may be due to climatic and peculiar soil conditions.

2. That moisture content is influenced by the factors of soil texture, irrigations, rain, evaporation and percolation.

3. That moderate rains will increase the moisture content (four-foot average) a fraction of one per cent; heavy rains will increase it from 1 to 2 per cent.

Proposed Irrigation Control

When sufficient experimental data are gathered to give definite indications of the optimum soil moisture content for different soil types, it is hoped that a system of plantation irrigation control based on moisture content may be adopted.

The purpose of the foregoing studies is stated by Mr. Wolters as follows: "The chief idea of this work is to aid toward the ultimate end of controlling irrigation scientifically on a plantation scale. Studies in soil moisture and growth in conjunction with water measurements are necessary to establish a basis or bases for drawing conclusions; and finally to formulate policies so as to be able to correlate them with practical experience and observation on irrigation practices."

The first step toward the establishment of such a control system has been the installation of experiments in the four type fields previously mentioned. In these tests, check plots (plantation practice) are compared with control plots. The check plots are irrigated at the same time as the surrounding crop cane. In the control plots, an irrigation is given whenever the soil moisture content reaches a "zero point," which, by experimentation, calls for an application of water. The "zero point" is not a fixed figure, since it is governed by seasonal variations. This point is established as a result of past experience, based on soil type, irrigations and rate of growth. Each soil type has its own "zero point."

Seasonal Averages
(Monthly Basis)

SOIL MOISTURE—IRRIGATION EXPERIMENTS
1928 Crop

SUMMARY OF RESULTS

Plant field—red silt loam, open, good drainage

	Temperature	Ac. Ins.	Moisture per cent	Growth inches
Summer (26)	77.2	3.59	29.05	8.95
Winter (26)	73.1	2.13	28.56	7.97
Spring (27)	73.8	2.30	31.76	10.98
Summer (27)	77.3	7.52	29.44	13.54
Ratoon field—tight, clay loam				
Summer (26)	74.6	3.20	30.46	10.48
Winter (26)	70.5	1.93	31.22	6.78
Spring (27)	70.9	2.50	33.18	8.76
Summer (27)	74.3	9.60	31.20	12.19
Ratoon field—red silt loam				
Summer (26)	77.2	4.05	28.64	14.54
Winter (26)	73.1	3.75	28.99	6.25
Spring (27)	73.8	5.40	32.39	9.67
Summer (27)	77.3	5.93	30.32	13.26

A comparison was recently made of four different irrigation systems:

1. Kauai modified Orchard.
2. Peru straight line.
3. Standard contour; 32-foot line.
4. Standard contour; 40-foot line.

The results, given below, were so conclusive that the experiment was not repeated:

	T.C.P.A.	Gals. Irr. water per T.C.	T.S.P.A.	Gals. Irr. water per T.S.	T.C.P.T.S.
Kauai modified Orchard.. ..	72.55	37,555.36	9.83	277,177.43	7.38
Peru straight line...........	73.83	43,832.69	10.22	316,650.46	7.22
Standard contour, 32′ line....	68.75	22,320.20	9.34	164,294.82	7.36
Standard contour, 40′ line...	70.95	23,209.43	9.98	165,000.09	7.11

A comparison of different combinations of length and width of watercourses is being made in an effort to determine the most economical and efficient method of applying irrigation water on different sections of the plantation. The combinations used are: 45 lines 30′ long, 30 lines 30′ long, 45 lines 35′ long and 30 lines 35′ long.

Acres per man-day, gallons per acre per man, and yield are the bases of comparison. Four experiments of this nature are being run on different parts of the plantation. The tests have been conducted for a comparatively short time and no definite results are as yet available.

Some Unusual Constituents Present in Common Fertilizers

By Fred Hansson

Introduction

In the past few years plant physiologists and chemists have found that certain of the so-called non-essential elements appear to be necessary for the normal development of a variety of plants. Maze (4), one of the first investigators to use specially purified salts in cultural solutions, found that minute quantities of boron, aluminum, bromine and iodine were apparently essential to the growth of green plants. McHargue (5, 6) has offered evidence as to the indispensability of manganese, zinc and copper for the normal development of certain plants. He worked with both cultural solutions and sand cultures and used purified salts. Miss Warington (10) worked with a species of broad bean in cultural solutions and discovered that boron up to certain concentrations stimulated the development of shoots and roots. Sommers and Lipman (7) concluded from their work with cultural solutions, using very pure salts and carefully controlled conditions, that zinc and boron are absolutely necessary to the life and growth of the higher green plants, such as sunflower, barley, mustard and flax. Allison, Bryan and Hunter (1) worked on the raw peat soils of the Florida Everglades and obtained a great response to applications of copper and manganese from corn, sorghum, peanuts and other plants.

The progress made by these investigators caused us to undertake an intensive study of the role of the rarer soil constituents as a part of our work, in the investigation of the growth failure of Lahaina cane. This work is now under way and will be reported in due season.

G. R. Stewart suggested that it would be desirable to know if we were supplying any of these rarer elements at the present time in the usual fertilizer materials. Nine samples of the more common materials used in making up mixed fertilizers were collected and analyzed for manganese, copper, zinc, boron, iodine, bromine and fluorine. The fertilizer materials selected were potash nitrate, German muriate of potash, American muriate of potash, sodium nitrate, ammonium sulphate, sulphate of potash, superphosphate, bone meal and dried blood. These ingredients form the basis of the major portion of the mixed goods at present supplied to the sugar plantations.

The results of the analyses are given in Table I:

Analytical Results

TABLE I

Percentage of some of the Unusual Constituents in the More Common Fertilizer Materials

Fertilizer Material	Per cent Manganese as MnO	Per cent Copper as Cu	Per cent Zinc as Zn	Per cent Boron as $Na_2B_4O_7$	Per cent Iodine as Iodide I	Per cent Iodine as Iodate I	Per cent Bromine as Bromide Br	Per cent Bromine as Bromate Br	Per cent Fluorine as Fluoride Fl
Nitrate of potash	Trace	None	None	0.404	Trace	.0240	0.0012	None	None
Muriate of potash (German)	Trace	None	None	Trace	Trace	None	0.094	None	None
Muriate of potash (American)	None	None	None	0.180	Trace	.0052	0.796	None	None
Nitrate of soda	.00046	None	None	0.095	Trace	.0104	Trace	None	None
Sulphate of ammonia	None	.00038	.035	Trace	None	None	None	None	0.145
Sulphate of potash	None	None	None	.0023	Trace	None	Trace	None	None
Superphosphate	None	None	None	None	None	None	None	None	Approx. 0.50
Bone meal	.0036	.00043	None	Trace	None	None	None	None	None
Dried blood	None	.00042	Trace	Trace	None	None	None	None	None

Summary of Results

Manganese (MnO): Appreciable traces of manganese were found in the potash nitrate and German muriate of potash. A small but determinable amount was present in the nitrate of soda and a much larger quantity in the bone meal.

Copper (Cu): Copper was found present in minute quantities in the sulphate of ammonia, bone meal and dried blood.

Zinc (Zn): Sulphate of ammonia was the only material which contained determinable amounts of zinc. The dried blood showed only a trace.

Boron ($Na_2B_4O_7$): Four of the fertilizer materials examined showed determinable amounts of boron. They were potash nitrate which contained the largest quantity, American muriate of potash, nitrate of soda and sulphate of potash. The German muriate of potash, sulphate of ammonia, bone meal and dried blood all showed a trace.

Iodine (I): The potash nitrate, German and American muriate of potash, nitrate of soda and sulphate of potash all showed traces of iodine as iodides. Most of the iodine, however, was present as iodates and occurred in the potash nitrate, American muriate of potash and nitrate of soda.

Bromine (B): Determinable amounts of bromine as bromides were found in the potash nitrate, German muriate of potash and the American muriate of potash. The quantity present in the latter fertilizer was quite large and would correspond to a content of 1.185 per cent of potassium bromide. No bromine as bromate was found present in any of the materials selected for analysis.

Fluorine (Fl): The element fluorine was found only in two of the samples. The sulphate of ammonia contained a small amount and the superphosphate a quite appreciable quantity.

As can be seen from the amounts of most of the rarer elements, present in our fertilizer materials, the quantities applied in our usual fertilizer applications would be quite small. An application of 1000 pounds of nitrate of potash corresponding to 145 pounds per acre of K_2O would contain boron equivalent to that in 4 pounds of anhydrous sodium borate, 3.8 ounces of iodine and 0.2 ounce of bromine. One hundred and fifty pounds per acre of K_2O supplied by the German muriate of potash would contain 4.5 ounces of bromine. The amount of American muriate of potash corresponding to an application of 150 pounds per acre of K_2O would also supply boron equivalent to 7.1 ounces of anhydrous sodium borate, 0.2 ounce of iodine and approximately 2 pounds of bromine. The nitrate of soda equivalent to an application of 100 pounds of nitrogen per acre would contain 1.0 ounce of anhydrous sodium borate, 1.1 ounces of iodine and 0.05 ounce of manganic oxide. The amount of the rarer constituents in the sulphate of ammonia corresponding to an application of 100 pounds of nitrogen per acre would be 0.03 ounce of copper, 2.7 ounces of zinc and 11.2 ounces of fluorine. Sulphate of potash when applied at the rate of 150 pounds of K_2O per acre also supplies boron equivalent to 0.1 ounce of anhydrous sodium borate. Superphosphate applied at the rate of 480 pounds per acre would furnish 100 pounds of P_2O_5 and 2.4 pounds of fluorine. In case bone meal was used to supply 100 pounds of P_2O_5 per acre, 0.2 ounce of

TABLE II

Amounts of some of the Unusual Constituents in Field Applications of the More Common Fertilizer Materials

Fertilizer	Application per acre (pounds)	Pounds Nitrogen per acre	Pounds K_2O per acre	Pounds P_2O_5 per acre	Manganese as MnO oz.	Copper Cu oz.	Zinc Zn oz.	Boron as $Na_2B_4O_7$ oz.	Iodine I oz.	Bromine Br oz.	Fluorine Fl oz.
Nitrate of potash	1000	145	145	...	Trace	....	....	4 lbs.	3.8	0.2	....
Muriate of potash (German)	300	...	150	...	Trace	....	....	Trace	Trace	4.5	....
Muriate of potash (American)	245	...	150	...	....	....	....	7.1	0.2	2 lbs.	....
Nitrate of soda	645	100	...	...	0.05	....	....	1.0	1.1	Trace	....
Sulphate of ammonia	485	100	...	...	....	0.03	2.7	Trace	....	....	11.2
Sulphate of potash	300	...	150	...	....	....	....	0.1	Trace	Trace	....
Superphosphate	480	...	...	100	....	....	....	....	....	....	2.4 lbs.
Bone meal	450	...	...	100	0.2	0.03	....	Trace	....	....	....
Dried blood	725	100	...	...	....	0,05	Trace	Trace	....	....	....

manganese as manganous oxide and 0.03 ounce of copper would also be added. The quantity of dried blood necessary to supply 100 pounds of nitrogen per acre contains 0.05 ounce of copper. The amounts of these unusual constituents found in field applications of the common fertilizer materials are given in tabular form in Table II.

In most of these fertilizer materials the amounts of many of these rarer constituents are so small that they probably would have but little effect on the plants. The larger quantities of boron present in the nitrate of potash and nitrate of soda might be sufficiently large to have a slight stimulating effect on sugar cane. From extensive experimental work on the mainland the U. S. Bureau of Soils concluded that more than 2 pounds of borax per acre would be toxic to most field crops. This does not seem to be true of sugar cane here in Hawaii. Stewart (8) found that the cane plant was not particularly sensitive to borates, and in the case of an application of 50 pounds of borax per acre there appeared to be some evidence of slight stimulation.

Some investigators have found that fluorides, bromides and iodides in minute quantities appear to cause an increase in growth on seed production. Aso (3) found that concentrations of 10 p. p. m. or less of sodium fluoride in cultural solutions had a slightly stimulative effect upon wheat, peas and barley. Working with peas in pot cultures, Suzuki (9) obtained an increase in growth and formation of fruit from small applications of potassium iodide. Aso (2) treated beans and rice in pots with small quantities of potasium bromide and obtained a response. We have no information available at present as to the effect of small quantities of fluorine, bromine or iodine upon sugar cane. Work is now under way to try to obtain some knowledge of their action upon cane shoots in cultural solutions.

LITERATURE CITED

(1) Allison, R. V., Bryan, O. C., and Hunter, J. H. 1927. The Stimulation of Plant Response on the Raw Peat Soils of the Florida Everglades Through the Use of Copper Sulphate and Other Chemicals. Bull. 190, Agr. Exp. Sta. Univ. of Florida.

(2) Aso, K. 1904-1905. Can Potassium Bromid Exert any Stimulating Action on Plants? Bull. of the College of Agr., Tokyo. Vol. VI, pp. 139-142.

(3) Aso, K. 1902-1903. On the Action of Sodium Fluorid upon Plant Life. Bull. of the College of Agr., Tokyo. Vol. V, pp. 187-195.

(4) Mazé, P. . 1915. Détermination des éléments minéraux rares nécessaires au dévelopement du maïs. Comptes Rendus Acad. Sci. 160, 211-214.

(5) McHargue, J. S. 1926. Manganese and Plant Growth. Jour. Ind. Eng. Chem. 18, pp. 172-175.

(6) McHargue, J. S. 1927. Significance of the Occurrence of Manganese, Copper, Zinc, Nickel and Cobalt in Kentucky Blue Grass. Jour. Ind. Eng. Chem. 19, pp. 274-276.

(7) Sommer, A. L., and Lipman, C. B. 1926. Evidence on the Indispensable Nature of Zinc and Boron for Higher Green Plants. Plant Physiology, Vol. 1, No. 3, pp. 231-249.

(8) Stewart, G. R. 1923. The Effect of Fertilizers Containing Borax Upon the Growth of Sugar Cane. Hawaiian Planters' Record, Vol. XXVII, pp. 201-206.

(9) Suzuki, S. 1902-1903. On the Action of Highly Diluted Potassium Iodid on Agricultural Plants. Bull. College Agri., Tokyo. Vol. V, pp. 199-201.

(10) Warington, Katherine. 1923. The Effect of Boric Acid and Borax on the Broad Bean and Certain Other Plants. Ann. Bot. 37, pp. 629-672.

The Influence of Nitrogen Fertilization on the Sucrose Content of Sugar Cane*

By W. P. Alexander†

This paper supplements a report made before the Academy two years ago, entitled "The Influence of Potash Fertilizer on Sucrose Content of Sugar Cane." At that time it was shown, contrary to published data on the subject, that under certain conditions potash fertilizer had had a beneficial effect on the sucrose content of cane. However, with nitrogen applications *in general* the reverse is true. This fact has been recognized in the literature and is commented upon frequently by those reporting the results of nitrogen fertilizer tests. It has been used as "an alibi" by those securing poorer sucrose content after an increase of nitrogen fertilizer, and perhaps too often nitrogen fertilizer has been blamed too severely for the low cane juices. A study was made at Ewa to determine from all available data at hand under the local environmental conditions, to what degree nitrogen fertilization in different amounts was responsible for less sucrose in the cane, and, if possible, to learn how this loss could be minimized and at the same time receive the fullest benefit from the fertilizer.

At the start it should be stated the purpose of nitrogen fertilization is to secure increased *sugar yields.* It is, therefore, possible to have in practice cases where the sugar yields are increased, even though the sucrose content is diminished. This will happen provided the cane yield is increased with the additional nitrogen so as to more than compensate for the lowering of the quality ratio. However, it is often found that the poorer juices that occur, may entirely offset the increase in cane yields and at times where there is no increase in the cane yields, the poorer juices may cause a decided loss in sugar secured. It is not the aim of this paper to stress the economic side of nitrogen fertilization, and gains or losses in cane and sugar yields will only be mentioned as a side issue to the main proposition, namely: The influence which nitrogen has on the juice of the cane *per se.*

Seventy-four nitrogen comparative field tests on sugar cane harvested since 1922 have been analyzed from this standpoint. How have the different amounts of nitrogen affected the quality ratio? How has the time of application affected the quality ratio? Is there an opportunity to better control fertilization so as to lessen the depression in sucrose content?

The Amount of Nitrogen Applied

A study of the accumulated data first impressed me with the fact that there was no constant loss due to nitrogen fertilization. As a general rule it was dis-

* Presented at the Hawaiian Academy of Science, May 18, 1928.

† Head Department of Agricultural Control and Research, Ewa Plantation Co.

covered that for each fifty pounds* of nitrogen per acre the quality ratio† would be reduced by slightly over two per cent. The frequency curve in Chart No. 1 illustrates the fluctuations obtained in sixty-one different "amount to apply" experiments with each increase of fifty pounds of nitrogen. The why and wherefore of this lack of regularity in the influence of nitrogen upon the sucrose content was investigated. First, there seemed to be some indications that as the nitrogen applications over 150 pounds increased the loss in sucrose content decreased.

The average data may be presented as follows (see Chart 2):
When an extra dose of 50 pounds is added:

To 250 lbs. the loss was 1.5%
To 200 lbs. the loss was 2.3%
To 150 lbs. the loss was 2.9%

In other words if one assumes a quality ratio of 8 with 150 pounds nitrogen then:

200 lbs. nitrogen	= 8.30 Q. R.	Difference 0.30 Q. R.
250 lbs. nitrogen	= 8.50 Q. R.	Difference 0.20 Q. R.
300 lbs. nitrogen	= 8.63 Q. R.	Difference 0.13 Q. R.

The above are very general figures showing as the amount of nitrogen is increased above a certain point the detrimental effect is less. There is a great deal of fluctuation between individual cases. An effort was made to correlate the differences in per cent loss in sucrose content due to nitrogen applications with the following factors:

1 Soil Type.
2 Date of Harvest.
3 Degree of Ripeness at Harvest.
4 Age of Cane at Harvest.
5 Proportion of Nitrogen applied between first and second seasons.
6 Interval Between Last Fertilization and Harvest.
7 Fertility of Soil as Shown by Yield—Cane per Acre per Month.

Except in the case of the first two mentioned—soil type and date of harvest—one is unable to find any relationship between varying effect of nitrogen on the sucrose content as shown in the quality ratio. There is not a clear cut case in even 1 and 2, but there is a tendency for fields of long ratoons, to be harvested in May, to be less affected by large doses of nitrogen; and short ratoons harvested in August and September seem to be able to better stand increases in nitrogen without so great a danger of injuring the quality ratio. Pali fields in the few instances avail-

* All nitrogen applications refer to an acre basis, i.e., 50 lbs. per acre.

† The sucrose content has been expressed in the term "quality ratio" which is understood to be the theoretical basis for the number of tons of cane required to produce one ton of sugar under certain arbitrary factory conditions. It reflects the more technical terms Brix, polarization and purity. To simplify the presentation of the data the actual quality ratio has not been stated, but reference is made to the per cent difference when various nitrogen treatments are reported.

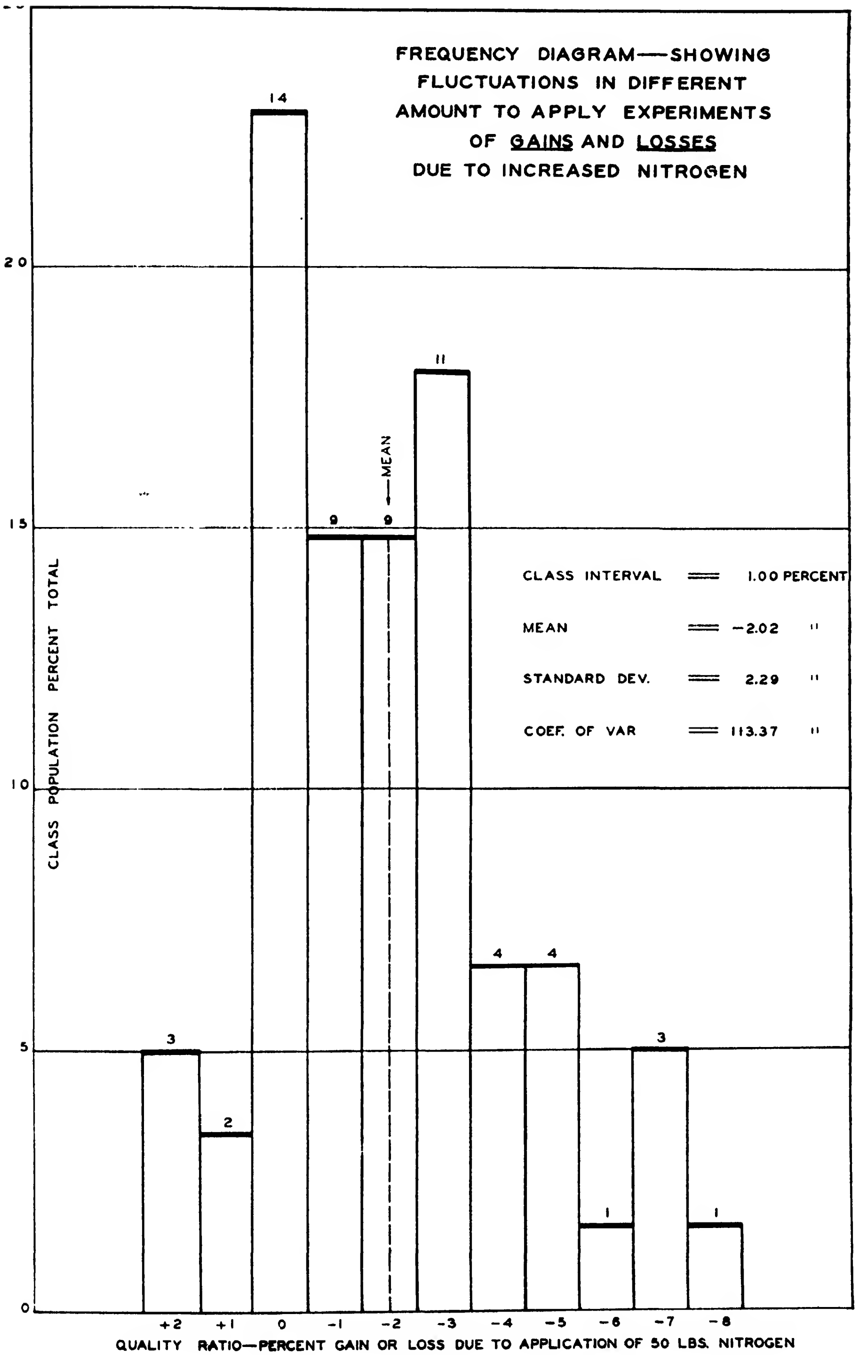

FREQUENCY DIAGRAM—SHOWING FLUCTUATIONS IN DIFFERENT AMOUNT TO APPLY EXPERIMENTS OF GAINS AND LOSSES DUE TO INCREASED NITROGEN
CLASS INTERVAL = 1.00 PERCENT
MEAN = -2.02 "
STANDARD DEV. = 2.29 "
COEF. OF VAR = 113.37 "
MEAN
CLASS POPULATION PERCENT TOTAL
QUALITY RATIO—PERCENT GAIN OR LOSS DUE TO APPLICATION OF 50 LBS. NITROGEN

Chart 1

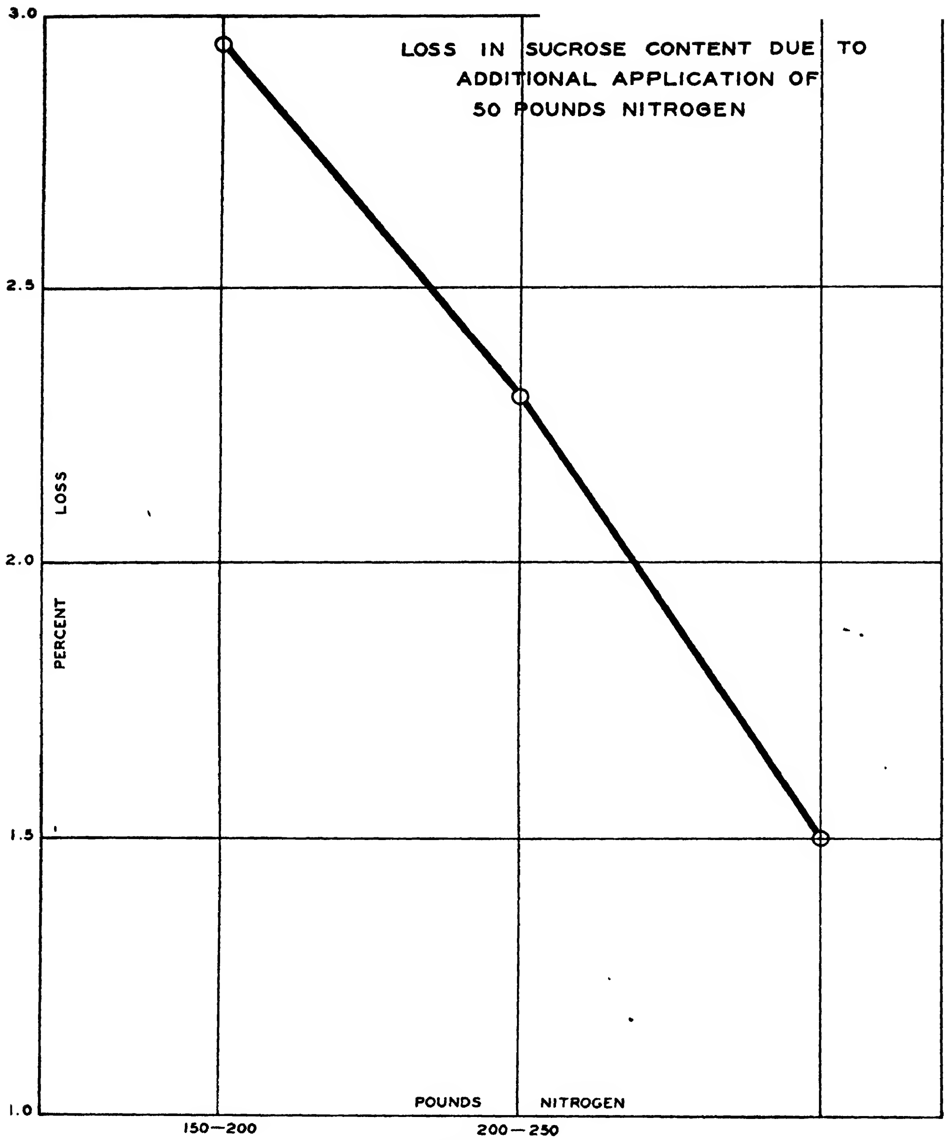

LOSS IN SUCROSE CONTENT DUE TO
ADDITIONAL APPLICATION OF
50 POUNDS NITROGEN
3.0
2.5
2.0
1.5
1.0
PERCENT LOSS
POUNDS NITROGEN
150—200
200—250

Chart 2

able show practically no detrimental effect on juices from nitrogen increases. The "wet" and coral fields also were less influenced. However, the cane juices in very fertile fields where fast-growing cane is to be found and nitrogen in the soil is higher, were often very adversely affected by more liberal applications of nitrogen.

One expected that the older a cane was, the more opportunity it would have to use up the excessive nitrogen or "wear off" the detrimental effects. However, the results from tests in 16A Pali (24.5 months old), 16C (23.3 months old) spoiled a correlation which tended to show that the juice of cane 20 to 24 months old was less influenced by increased nitrogen.

There is prevalent a notion that large amounts of nitrogen will do no harm if applied so as to give at least twelve months between the last dose and harvest. Also, by putting the larger portion on in the first season, increased amounts of nitrogen will have less detrimental effect on the cane juice. This was not shown in the analysis of the data. With a non-fertilizer interval from 8.8 to 15 months no consistent difference could be detected. There were wide fluctuations in the results irrespective of in what proportions the nitrogen was applied, viz.:

First Season	Second Season
1/4	3/4
1/3	2/3
7/12	5/12
2/3	1/3

It was rather surprising to find that these tests did not show that the degree of ripeness at harvest was a factor in determining how great the influence of different doses of nitrogen would be on the sucrose content. For example, with long ratoons, Field 16C with an 8 Q. R. showed a 4.84 per cent loss, and 23C with a 9 Q. R. a 4.12 per cent loss due to increasing the total nitrogen from 200 to 250 pounds; and in short ratoons Field 19D with 7.5 Q. R. had a 7.64 per cent loss due to boosting nitrogen from 150 to 200, and Field 22A with 8.7 Q. R. had a 6.6 per cent loss due to boosting nitrogen from 200 to 250.

Finally, whether the cane was grown on a very fertile or on rather poor soil (as shown by the yields of *cane-per-acre-per-month*) seemed to make little difference in the great variation in the effect of nitrogen on sucrose content.

Nitrogen Fertilization Correlated With Quality Ratio and Yield

The results from the tests dealing with amount of nitrogen to apply were placed in sixteen groups according to relation of the quality ratio to the cane and sugar yields. These data are summarized below:

STUDY OF INFLUENCE OF NITROGEN FERTILIZATION
AVERAGES OF TESTS GROUPED ACCORDING TO RESULTS

								Q. R. Plot to Plot Comp.			
Lbs. N	Cane...........	Q. R...........	Sugar..........	No. of Tests......	Per cent Cane...	Per cent Q. R....	Per cent Sugar...	Total..........	For 300..........	Same..........	For 250..........
300 vs. 250	Loss	Loss	Loss	2	—2.53	—2.14	—4.53	14	5	1	8
(See Table I)	Same	Loss	Loss	5	+0.23	—3.65	—3.38	41	5	4	32
	Loss	Same	Loss	2	—2.31	—0.08	—2.36	17	4	3	10
	Same	Same	Same	6	+0.86	—0.68	+0.13	36	13	5	18
	Gain	Same	Gain	2	+3.51	+0.14	+3.63	18	5	7	6
	Gain	Gain	Gain	1	+2.69	+2.07	+4.84	15	8	2	5
	Total Experiments......			18							
250 vs. 200	Loss	Loss	Loss	2	—2.21	—3.02	—5.00	13	3	0	10
(See Table II)	Same	Loss	Loss	6	+0.37	—2.77	—2.34	34	7	2	25
	Gain	Loss	Loss	2	+4.93	—6.33	—1.29	17	2	0	15
	Loss	Same	Loss	1	—2.28	+0.46	—1.83	5	1	1	3
	Same	Same	Same	5	+0.03	+0.21	+0.26	42	21	3	18
	Gain	Loss	Same	2	+5.84	—5.36	+0.46	13	3	2	8
	Gain	Loss	Gain	8	+7.43	—2.74	+4.52	57	15	5	37
	Gain	Same	Gain	5	+4.00	—0.40	+3.57	36	16	5	15
	Total Experiments......			32							
200 vs. 150	Gain	Loss	Same	6	+4.05	—3.99	+0.04	39	1	5	33
(See Table III)	Gain	Loss	Gain	3	+9.15	—3.11	+5.87	19	3	1	15
	Gain	Same	Gain	1	+2.79	—0.25	+2.52	13	5	1	7
	Gain	Gain	Gain	2	+2.20	+1.70	+3.89	13	9	0	4
	Total Experiments......			12							

Considering first the comparison of 300 pounds of nitrogen with 250 pounds, the outstanding features seem to be: (1) that in less than half of the experiments the sucrose content was depressed by additional nitrogen; (2) that cane yields were not necessarily increased when the quality ratio was poorer; (3) that except in three instances out of eighteen, sugar yields were not benefited by 300 pounds of nitrogen over 250 pounds.

Considering next the comparisons of 250 pounds of nitrogen with 200 pounds the 32 tests show: (1) that the added nitrogen has caused lower juices in 21 cases; (2) that gains in cane yield have been completely offset in 4 instances and have counterbalanced a poorer quality ratio in 8 instances; (3) that only in 13 out of 32 tests was 250 pounds nitrogen profitable over 200 pounds; (4) that in 11 tests a small loss in sugar resulted from the heavier nitrogen dose.

Finally, considering 12 experiments which compared 200 pounds nitrogen with 150 pounds the results were: (1) that losses in quality ratio were compensated by larger cane yields in 9 tests, 3 of which gave sugar increases; (2) that in 4 tests the gain in cane was not accompanied by a poorer quality ratio; (3) that in the 9 instances where poorer juices did occur they were very consistently (plot to plot) harmful to the quality ratio.

In general, the conclusions to be drawn from these results are: (1) as the amount of nitrogen is increased above 150 pounds, the depression in sucrose content is greatest in the first additional 50 pounds accompanied by a substantial gain in cane; (2) that there is less influence on both cane and quality from 200 pounds to 250 pounds, but a tendency for the benefit of increased cane tonnage to be lost from a poorer quality ratio; (3) that if the nitrogen is boosted from 250 pounds to 300 pounds (a) the likelihood of bettering cane yields is small and there is some chance of actually injuring cane yields, (b) the accompanying juices will be affected detrimentally, but without cane increases, (c) the sugar yields do not usually respond to this heaviest fertilization.

From the point of view of the proper maturing of the cane with the *maximum sugar yields,* nitrogen, it is seen, has a very injurious influence when the total amount goes over 250 pounds. Even between 200 and 250 pounds some discretion is necessary if the juices are not to be depressed slightly.

The Time of Application

The results from four tests comparing the time of application favor only one early dose in the second season rather than dividing the nitrogen into one early dose (March) and one late dose (May or June). The data are summarized below:

SECOND SEASON—ONE VS. TWO DOSES—BY HAND
Base is One Dose

Field	Crop	Gain for 1 Dose per cent Cane	Gain for 1 Dose per cent Q. R.	Gain for 1 Dose per cent Sugar	Q. R.—Plot to Plot Comp. Total	For 1	Same	For 2
1A	1923	5.95	0.78	6.85	6	1	3	2
1G	1926	—0.33	—0.81	—1.12	16	8	0	8
3B	1924	0.44	0.79	1.30	6	2	..	4
11	1923	2.35	1.35	3.93	6	2	2	2
		+2.10	+0.53	+2.74	34	13	5	16

Also in the case of short ratoons the poorer juices resulted from two doses in March and July as compared with one dose in April. Here, however, two applications had better cane yields in two instances, which made the data rather inconclusive:

SHORTS—ONE VS. TWO DOSES

Base is Two Doses

Field	Crop	Gain for 2 Doses per cent Cane	Gain for 2 Doses per cent Q. R.	Gain for 2 Doses per cent Sugar	Q. R.—Plot to Plot Comp. Total	For 2	Same	For 1
1G	1924	5.59	—3.81	1.74	9	2	1	6
1G	1927	4.19	—2.68	1.54	10	1	1	8
3B	1925	—0.09	—3.88	—4.14	17	1	3	13
3C	1926	1.21	—3.49	—2.02	16	1	3	12
10A	1926	—0.21	—5.56	—6.17	5	0	1	4
Average and Totals..		+2.14	—3.88	—1.81	57	5	9	43

The indications are that there is a very good opportunity to obtain the best sucrose content by an early dose, but there is some danger of not producing enough cane tonnage to give highest sugar returns.

Three experiments on early cut cane for the 1928 crop have been harvested comparing the effects of the following applications of nitrogen:

	(1)	(2)
July	100	50
August	...	50
October	100	...
March	50	150
Total	250	250

The results favored treatment No. 1 as shown below:

Field	Cane Started	Per cent Cane Gain for Treatment No. 1	Per cent Q. R. Gain or Loss for Treatment No. 1	Per cent Sugar Gain for Treatment No. 1	Q. R.—Plot to Plot Comp. Total	For 1	Same	For 2
13B	May 13	+1.30	—0.85	+0.44	4	1	0	3
16A	April 12	+2.79	+5.23	+8.46	5	4	0	1
16B	April 17	+1.17	+2.11	+3.36	5	4	1	0
Average and Totals.....		+1.75	+4.09	+4.09	14	9	1	4

Therefore one may say, negatively, that very large applications of nitrogen should not be applied in the second season when the cane is nine to eleven months old, especially if the field is going to be harvested within a year of the last dose. The injury to sucrose content of an additional 100 pounds of nitrogen in the second season was responsible for a severe loss.

The danger of injuring sucrose content with nitrogen fertilizer appears to be greatest in the second season in even younger cane as shown by the following test:

Cane started July 23	Treatment No. 3	Treatment No. 4
October	100 lbs. N	50 lbs. N
February	125 lbs. N	50 lbs. N
April	....	125 lbs. N

Field	Per cent Cane Gain for Treatment No. 3	Per cent Q. R. Gain for Treatment No. 3	Per cent Sugar Gain for Treatment No. 3	Q. R.—Plot to Plot Comp. Total	For 3	Same	For 4
3B	+3.17	+6.22	+10.09	6	6	0	0

Conclusions

More cane per ton of sugar is required when cane is fertilized with nitrogen to offset the depressing effect on sucrose content. This depressing effect varied greatly, averaging about 2 per cent for each 50 lbs. of nitrogen over 150 lbs. with a standard deviation of ± 2.3. When the cane responded to additional doses of 50 pounds of nitrogen starting at 150 pounds per acre, the loss in quality ratio averaged 3 per cent for the first increase to 200 pounds, 2.3 per cent up to 250 pounds and 1.5 per cent for the last increase up to 300 pounds. The juice of cane grown on the pali and coral soil types was less influenced by nitrogen applications. When cane was harvested at the time when it ripens normally, i.e., in May, the juices were better, irrespective of nitrogen treatment. Conversely, cane harvested in the early season suffered more from added nitrogen.

Extra cane yields usually offset the lower juices when the 150-pound dose was boosted to 200 pounds, often compensated for the poorer quality ratio in the jump from 200 pounds to 250 pounds, and seldom counterbalanced the reduction in sucrose content when 300 pounds was applied.

The key to profitable fertilization with heavy doses of nitrogen is the application at the proper time. There is a point in the cane's growth when no further nitrogen, or only small quantities, can be applied with safety. Great care must be exercised in not giving the cane overdoses in the second season.

TABLE I

STUDY OF EFFECT OF NITROGEN ON SUCROSE CONTENT
300 Lbs. N. Versus 250 Lbs. N.

		Per cent Gain or Loss				Plot to Plot Comp.		
		Cane	Q. R.	Sugar	Total	For 300	Same	For 250
		Sugar Loss, Cane Loss, Q. R. Loss						
19D	1926	—3.33	—2.75	—5.86	5	2	0	3
16C	1924	—1.72	—1.53	—3.20	9	3	1	5
		—2.53	—2.14	—4.53	14	5	1	8
		Sugar Loss, Cane Same, Q. R. Loss						
1G	1926	+0.95	—6.80	—5.48	11	1	0	10
6	1926	+0.09	—3.19	—2.99	4	0	1	3
23A	1927	+0.10	—4.78	—4.48	7	1	0	6
2A	1925	+0.25	—1.39	—1.61	4	0	1	3
23B	1924	—0.25	—2.09	—2.35	15	3	2	10
		+0.23	—3.65	—3.38	41	5	4	32
		Sugar Loss, Cane Loss, Q. R. Same						
23C	1927	—2.22	+0.62	—1.57	8	2	1	5
14C	1927	—2 40	—0.78	—3.15	9	2	2	5
		—2.31	—0.08	—2.36	17	4	3	10
		Sugar Same, Cane Same, Q. R. Same						
13C	1925	+0.06	—1.26	—1.21	4	2	1	1
16C	1926	+0.94	—0.12	+0.80	7	2	1	4
22A	1924	+0.38	......	+0.32	5	3	1	1
23B	1927	+0.08	—1.03	—0.91	7	2	1	4
23C	1925	+1.24	—1.33	—0.07	8	3	..	5
13B	1926	+2.44	—0.35	+0.27	5	1	1	3
		+0.86	—0.68	—0.13	36	13	5	18
		Sugar Gain, Cane Gain, Q. R. Same						
22A	1927	+4.18	———	+4.17	3	1	0	2
3A	1924	+2.84	+0.27	+3.09	15	4	7	4
		+3.51	+0.14	+3.63	18	5	7	6
		Sugar Gain, Cane Gain, Q. R. Gain						
8A	1926	+2.69	+2.07	+4.84	15	8	2	5

TABLE II

STUDY OF EFFECT OF NITROGEN ON SUCROSE CONTENT

250 Lbs. N. Versus 200 Lbs. N.

		Per cent Gain or Loss				Plot to Plot Comp.		
		Cane	Q. R.	Sugar	Total	For 250	Same	For 200
		Sugar Loss, Cane Loss, Q. R. Loss						
16C	1926	—2.94	—4.84	—7.39	9	1	0	8
13C	1923	—1.48	—1.19	—2.60	4	2	0	2
		—2.21	—3.02	—5.00	13	3	0	10
		Sugar Loss, Cane Same, Q. R. Loss						
6	1926	+0.10	—3.30	—3.12	5	1	1	3
13C	1925	+0.89	—1.92	—0.99	5	1	1	3
23C	1925	+0.41	—3.13	—2.63	9	2	0	7
16A (P)	1924	—0.23	—2.83	—3.00	4	1	..	3
16A	1926	+0.43	—1.53	—1.13	5	1	..	4
1G	1927	+0.63	—3.88	—3.15	6	1	..	5
		+0.37	—2.77	—2.34	34	7	2	25
		Sugar Loss, Cane Gain, Q. R. Loss						
3A	1926	+6.00	—7.36	—1.22	13	2	0	11
16A (P)	1926	+3.86	—5.29	—1.36	4	0	0	4
		+4.93	—6.33	—1.29	17	2	0	15
		Sugar Loss, Cane Loss, Q. R. Same						
13B	1926	—2.28	+0.46	—1.83	5	1	1	3
		Sugar Same, Cane Same, Q. R. Same						
16C	1924	—0.84	......	—0.84	10	4	0	6
23A	1927	+0.88	+1.01	+1.97	8	5	0	3
23B	1927	+0.53	—0.39	+0.14	5	1	1	3
13C	1926	—0.22	—0.34	—0.55	4	2	1	1
23B	1925	—0.18	+0 78	+0.59	15	9	1	5
		+0.03	+0.21	+0.26	42	21	3	18
		Sugar Same, Cane Gain, Q. R. Loss						
23C	1927	+4.72	—4.12	+0.58	8	2	2	4
22A	1925	+6.95	—6.60	+0.34	5	1	..	4
		+5.84	—5.36	+0.46	13	3	2	8
		Sugar Gain, Cane Gain, Q. R. Loss						
1G	1926	+ 6.48	—3.13	+3.28	7	2	2	3
3A	1924	+11.09	—1.80	+9.17	15	5	1	9
22A	1924	+ 7.08	—3.09	+3.88	4	2	..	2
22A	1927	+10.04	– 1.35	+8.57	5	2	..	3
2A	1927	+ 8.17	—5.40	+2.65	4	..	1	3
16A	1924	+ 3.87	—1.21	+2.50	4	..	..	4
23B	1924	+ 6.85	—3.89	+2.36	10	2	0	8
1G	1924	+ 5.85	—2.03	+3.78	8	2	1	5
		+7.43	—2.74	+4.52	57	15	5	37
		Sugar Gain, Cane Gain, Q. R. Same						
14C	1927	+1.62	—0.45	+1.16	8	4	1	3
19D	1926	+6.97	—1.09	+5.75	5	2	0	3
B	1927	+2.38	+0.26	+2.68	11	5	1	5
2A	1925	+3.11	—0.23	+2.85	6	3	0	3
3C	1926	+5.92	—0.48	+5.41	6	2	3	1
		+4.00	—0.40	+3.57	36	16	5	15

TABLE III

STUDY OF EFFECT OF NITROGEN ON SUCROSE CONTENT
200 Lbs. N. Versus 150 Lbs. N.

		Per cent Gain or Loss			Plot to Plot Comp.			
		Cane	Q. R.	Sugar	Total	For 200	Same	For 150
		Sugar Same, Cane Gain, Q. R. Loss						
1G	1927	+3.48	—3.59	—0.19	6	0	0	6
13C	1926	+2.53	—2.79	—0.28	5	0	0	5
19D	1927	+6.94	—6.64	+0.21	3	0	0	3
19G	1926	+2.55	—1.90	+0.62	7	0	2	5
23B	1925	+5.44	—6.25	—0.78	10	1	1	8
1G	1924	+3.38	—2.74	+0.65	8	0	2	6
		+4.05	—3.99	+0.04	39	1	5	33
		Sugar Gain, Cane Gain, Q. R. Loss						
3C	1926	+ 8.98	—2.43	+6.42	7	1	0	6
13C	1923	+10.73	—4.22	+6.25	5	1	1	3
15B	1926	+ 7.73	—2.69	+4.93	7	1	0	6
		+ 9.15	—3.11	+5.87	19	3	1	15
		Sugar Gain, Cane Gain, Q. R. Same						
24A	1926	+2.79	—0.25	+2.52	13	5	1	7
		Sugar Gain, Cane Gain, Q. R. Gain						
C	1926	+2.72	+1.54	+4.28	8	6	0	2
22A	1925	+1.67	+1.85	+3.50	5	3	0	2
		+2.20	+1.70	+3.89	13	9	0	4

TABLE IV

CROP DATA FOR NITROGEN EXPERIMENTS

	Soil Type	Field	Crop	Quality Ratio Per cent Gain or Loss for 50 Pounds Nitrogen 150–200 lbs.	200–250 lbs.	250–300 lbs.	Date Harvested		Cane Age (Mos.)	Cane per Acre per Month	Q. R.	Int. Last Fert. and Harvest (Mos.)	Proportion 1st and 2nd Season Fertilizer Application	
Long Ratoons	General	1G	1926	......	—3.13	—6.80	March	14	19.4	5.82	9.27	11.0	1/3	2/3
	General	2A	1925	......	—0.23	—1.39	April	2	23.9	5.45	8.63	12.6	2/3	1/3
	General	2A	1927	......	—5.40	......	Jan.	21	21.6	5.33	8.71	10.7	7/12	5/12
	General	6	1926	......	—3.30	—3.19	April	1	20.6	6.33	9.70	12.9	7/12	5/12
	General	14C	1927	......	—0.45	—0.78	May	30	25.8	5.66	8.95	14.5	1/2	1/2
	General	16A Pali	1924	......	—2.83	......	April	1	20.5	6.62	8.48	12.8	2/3	1/3
	General	16A Pali	1926	......	—5.29	......	April	16	24.5	4.99	8.31	13.5	7/12	5/12
	General	16A	1924	......	—1.21	......	May	17	22.9	5.92	8.28	14.3	2/3	1/3
	General	16A	1926	......	—1.53	......	April	14	22.8	5.42	8.24	13.4	7/12	5/12
	General	19D	1926	......	—1.09	—2.75	Feb.	15	17.7	5.21	8.28	9.3	1/3	2/3
	General	23A	1927	......	—1.01	—4.78	Jan.	29	21.7	5.19	8.87	11.2	2/3	1/3
	General	23B	1924	......	—3.89	—2.09	Jan.	8	17.6	5.55	8.74	9.8	1/2	1/2
	General	23B	1927	......	—0.39	—1.03	June	15	23.0	4.80	7.70	14.5	1/4	3/4
	General	23C	1925	......	—3.13	—1.33	March	11	21.9	5.56	8.00	12.3	2/3	1/3
	General	23C	1927	......	—4.12	+0.62	Feb.	11	21.2	5.80	8.97	11.5	2/3	1/3
	Wet	3A	1924	......	—1.80	+0.27	April	30	18.3	3.28	7.23	12.2	1/3	2/3
	Wet	3A	1926	......	—7.36	+2.07	Feb.	5	21.2	4.31	8.56	12.1	7/12	5/12
	Semi-Wet	16C	1924	......	Same	—1.53	May	7	23.0	6.15	8.47	13.9	2/3	1/3
	Semi-Wet	16C	1926	......	—4.84	—0.12	April	16	23.3	5.15	8.06	13.6	7/12	5/12
	Coral	22A	1924	......	—3.09	Same	Dec.	28	21.8	4.01	9.70	8.8	2/3	1/3
	Coral	22A	1927	......	—1.35	Same	Jan.	11	18.0	5.97	10.34	9.5	1/3	2/3
	Semi-Coral	13B	1926	......	+0.46	—0.35	May	25	22.0	5.16	8.68	15.0	7/12	5/12
	Semi-Coral	13C	1925	......	—1.92	—1.26	Feb.	10	20.3	6.56	9.38	11.1	2/3	1/3
	Pali	B	1927	......	+0.26	......	May	22	24.2	4.83	7.84	13.4	1/3	2/3
Short Ratoons	General	1G	1924	—2.74	—2.03	......	July	29	17.6	4.70	7.67	13.2		
	General	1G	1927	—3.59	—3.88	......	Aug.	13	17.0	5.24	8.36	12.7		
	General	15B	1926	—2.69	......	......	Aug.	14	17.6	4.80	7.43	13.5		
	General	19D	1927	—7.64	......	......	June	18	16.1	4.38	7.53	11.1		
	General	23B	1925	—6.25	—0.78	......	July	16	18.4	4.24	7.65	12.9		
	Wet	C	1926	+1.54	......	......	July	21	16.8	4.80	9.09	12.7		
	Wet	3C	1926	—2.43	—0.48	......	July	23	19.1	3.89	8.22	13.0		
	Coral	22A	1925	+1.85	—6.60	......	July	12	18.5	4.01	8.65	12.9		
	Semi-Coral	13C	1923	—4.22	—1.19	......	May	31	14.5	3.83	8.06	10.3		
	Semi-Coral	13C	1926	—2.79	—0.34	......	Aug.	18	18.3	5.11	8.60	13.6		
	Semi-Coral	19G	1926	—1.90	......	......	Aug.	5	17.9	4.57	8.43	13.2		
	Pali	24A	1926	—0.25	......	......	July	9	17.5	4.09	7.85	12.7		

The Treatment of Acid Mauka Soils in the Propagation of a Forest Cover

By F. E. Hance

The following paper is based on the results of an investigation of ten distinctive soil types which, at present, prevail on the high altitudes of Kapalama, Oahu.

Through the courtesy of Albert F. Judd, acting for the Bishop Estate, we have been supplied with generous samples of all soil types for experiment and investigation. Mr. Judd has experienced difficulty in securing satisfactory progress in the growth of many of the young trees which have been set out in these areas. An undetermined environmental condition exists which markedly inhibits the development of young tree shoots and yet apparently has but little adverse effect upon surviving trees entering the stage of growth which borders on maturity.

On an inspection of the area with Mr. Judd in March of this year, Mr. Agee recognized a soil condition of dispersion or puddling as the common phenomenon apparently associated in many instances with the tree failure which he had observed.

Having met with similar soil conditions in cane lands, our major problem for the past few years, we secured several samples of representative soil types for experiment at this Station. Mr. Stewart and the writer arranged and conducted a program of investigation, the results of which are herewith presented. By considering the physical characteristics of the soil we found that determinations of reaction, as regards acidity or alkalinity, would give us ample information for inaugurating a progressive corrective treatment. Mr. Nesbitt made the reaction determinations referred to above, both in the various soils as received and in the same samples after treatment and cultivation. His findings appear in the data with other observations.

All the samples were found to be acid in reaction, sticky and claylike in texture and practically impervious to the movement of water. Originating in regions of heavy rainfall one would expect such soils to be deficient in the more common soluble nutrients and to contain excessive amounts of the toxic products resulting from the hydrolysis of aluminum and kindred compounds.

The excessive degree of dispersion or puddling which prevailed is known to act as a barrier to the necessary penetration of atmospheric air to the zone of the plant roots. Few trees would survive planting in concrete and yet to some extent similar conditions were met with at Kapalama.

It followed then that any corrective measure should include an admixture with the soil of some easily obtainable material which would mechanically improve soil granulation and thus assist in normal aeration. The subject of plant nutrients was also considered. The difficulty in transportation of bulk fertilizer to mauka

regions necessitated the employment of the most highly concentrated and effective fertilizer obtainable, provided that a fertilizer treatment was found to be essential.

Mr. Stewart, Dr. Lyon and the writer have found, separately, in other investigations, that acid soils invariably respond to applications of raw rock phosphate. This fact led us to include this material as a likely addition of desirable possibilities. An attempt to correct the puddled condition of the soil by a chemical replacement of the bases which cause the conditions was not considered a practical measure. The labor and material required in such a program would involve prohibitive costs. We deemed it advisable, however, to test the effectiveness of base replacement with gypsum upon the physical condition of these soils. In line with the scheme of adding materials which assist in producing soil granulation we decided to try out the recently developed bagasse-molasses-press cake mixture which has given such good results with some cane land.

The total amount of soil available for the experiment was about 30 pounds of each distinctive type.

Due to its rapid growth and early development of symptoms, which are indicative of potash deficiency and aluminum toxicity, we selected White Guam corn as a test crop to judge the probable effect of the various soil treatments on tree growth. Accordingly we divided separately the ten distinctive soil samples into five lots of about six pounds each for treatment as follows:

1. Incorporation with soil of 3 per cent bagasse molasses mixture (molashcake).
2. Incorporation with soil of 3 per cent rice hulls.
3. Incorporation with soil of 3 per cent gypsum.
4. Incorporation with soil of 3 per cent raw rock phosphate.
5. Control—no treatment.

We must make it clear that our primary consideration was chiefly concerned with obtaining positive indications on the effect of the above widely divergent soil treatments. When considered in terms of pounds-per-acre-foot of soil, a 3 per cent addition of any corrective is impractical. However, in the case of soil treatment per tree (radius of 2 to 3 feet) at intervals of 20 to 30 feet, the practice becomes at once an economic expedient. Therefore, having prepared the soil as outlined above we placed it in six-pound clay pots and planted corn therein on March 22, 1928.

When the sprouts appeared, daily observations were made until the plants became pot-bound. After five weeks of growth, W. Twigg-Smith very kindly photographed the entire experiment in individual groups of each soil type. The photographs are later presented with explanatory headings and sub-titles.

Growth measurements were made on April 5, and again on April 20. The average increment of growth for the fifteen-day period in each pot is recorded in the data. Stated briefly our observations were as follows:

Molashcake (molasses, bagasse and press cake): In the short period of time in which this material was in the soil, but little influence on the plants was observed. A striking exception was in soil Type I, where an unusual response was obtained. In most cases this mixture resulted in a marked reduction of soil acidity, and in

all cases it improved the tilth of the soil. Response of molashcake with cane usually is evident only after an interval of about two to three months.

Gypsum: Valuable experience was gained in experimenting with this reagent in Kapalama acid soils. Replacement reactions were accomplished with unusual rapidity. Flocculation of the soil was secured in every case with the accompanying correction of the dispersed or impervious condition. In most cases an increase in soil acidity resulted from the chemical reactions occasioned by the presence of the gypsum. Apparently this increase in acidity added to the toxic influence of the aluminum and ferrous iron originally present in the soil. All plants grown in gypsum treated soil showed pronounced symptoms of aluminum toxicity.

Rice Hulls: The admixture of this fibrous material with the soil resulted in remarkable development and growth in each soil type. The favorable results can scarcely be attributed to the high phosphate content of the hulls in such a short time. We are inclined to place the credit on the mechanical effect secured through aeration and drainage. The plants grown in rice hulls were luxuriant, but evidences were common of potash starvation and aluminum toxicity. No decided improvement in soil reaction (reduction of acidity) was secured in any type.

Raw Rock Phosphate: The employment of this material was fully justified by the remarkable growth observed in both plants and root systems. In most of the soil types the acidity was materially reduced. Unusual response to this reagent was realized in each soil type. Compared with controls the increment of growth expansion increased by a margin which varied between 200 and 600 per cent. Regardless of the physical condition or chemical character of any of the soils, raw rock phosphate gave immediate response.

Controls: All control or untreated soils produced plants which were severely stunted and chlorotic.

In the appended photographs the numerals indicate the ten classes of soils which Mr. Judd submitted. We have no data on soil collections, so no description of this phase of the investigation can be made. Each plate illustrates the variability of growth secured in a particular soil type after treatment (viewed from left to right) as follows:

Molashcake (bagasse-molasses-press cake);
Rice hulls;
Gypsum;
Raw rock phosphate;
Control (no treatment).

The writer recently visited the Kapalama regions with Mr. Judd and Dr. Lyon. The subject of a general soil survey was discussed. Mr. Judd advanced a proposal, the substance of which embraced the desirability of learning the complete chemical composition of all soil types which exist in the above-mentioned region. From this knowledge he planned to vary his planting program so as to include only the varieties of trees which flourished in similar soils in other parts of the tropics. While this plan would probably work to good advantage we feel that the variability

imposed by differences in climate, moisture, wind intensity, acclimation of variety, etc., would, to a great extent, nullify comparisons on a strictly soil basis. The fact that large trees are growing in a normal manner at Kapalama points, we think, to the logical conclusion that the deeply growing roots are securing all the necessary nutrients that the plant requires. Depletion of nutrients and dispersion of soil particles is undoubtedly confined to the few surface feet of soil which are subject to erosion.

Therefore, we recommend that young trees be planted in such a manner that will encourage the rapid development of hardy roots. Select the location, dig a deep post hole, remove soil and incorporate with it a good supply of raw rock phosphate, potash nitrate and rice hulls. Return the prepared soil to the hole and plant as

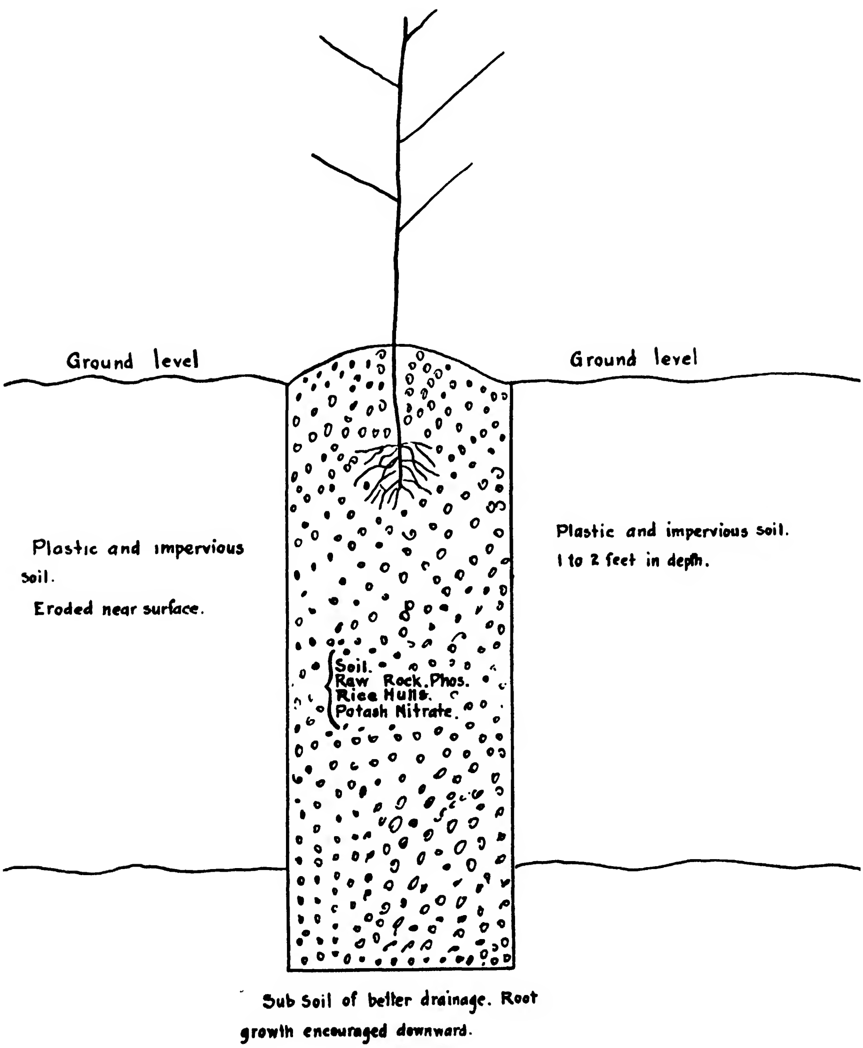


Fig. 1

usual. Mound the soil up at the base of the tree to insure a higher level than the surrounding area. This plan is proposed with the knowledge that many of the prepared holes will immediately fill with water. A displacement of water will take place as the hole is refilled and thereafter drainage, aeration and the higher level of soil at base of tree should take care of the water situation.

Another important point in this plan is the fact that the materials proposed are not readily dissipated by protracted leaching, therefore placing the treatment in a water soaked area should not nullify the corrective effect desired.

The raw rock phosphate will tend to render aluminum salts insoluble and harmless. It will reduce soil acidity and supply the very valuable phosphates which the soil has been shown to require.

Potash nitrate will supply a primary nitrogen boost and place a reserve of K_2O in a fixed but available form. The admixture of rice hulls should result in good aeration and drainage for several years. We feel confident that this treatment will materially assist in enabling the young tree to become firmly established. The recommendation is illustrated as a hypothetical case in Fig. 1.

We have received from Mr. Judd large samples of Type 1 and Type 9 soils.

It is our plan to experiment in growing trees in these soils, following the proposals in the recommendations made above.

KAPALAMA SOILS—CORN EXPERIMENTS—PLANTED MARCH 22, 1928

pH determinations by C. W. Nesbitt

Description	Pot No.	Soil No.	Soil reaction pH before treatment	Soil reaction pH after treatment	Height of corn plants April 5, inches	Height of corn plants April 20, inches	15 days of growth, inches
Molashcake	1	1	4.19	4.36	7.8	22.0	14.2
Hulls	2	1	4.19	4.94	5.5	19.0	13.5
Gypsum	3	1	4.19	4.63	6.8	16.5	9.7
Raw rock	4	1	4.19	6.09	9.0	24.5	14.5
Control	5	1	4.19	5.00	5.3	13.0	7.7
Molashcake	6	2	4.58	4.73	7.0	17.5	9.5
Hulls	7	2	4.58	5.04	8.5	19.0	10.5
Gypsum	8	2	4.58	4.63	8.7	15.5	6.8
Raw rock	9	2	4.58	5.70	9.0	22.0	13.0
Control	10	2	4.58	5.06	7.8	12.5	3.7
Molashcake	11	3	5.11	6.46	5.7	10.5	4.8
Hulls	12	3	5.11	4.89	7.5	17.5	10.0
Gypsum	13	3	5.11	4.72	9.0	15.5	5.5
Raw rock	14	3	5.11	6.02	9.8	21.0	11.2
Control	15	3	5.11	4.80	5.7	9.5	3.8

Description	Pot No.	Soil No.	Soil reaction pH before treatment	Soil reaction pH after treatment	Height of corn plants April 5, inches	Height of corn plants April 20, inches	15 days of growth, inches
Molashcake	16	4	4.61	6.49	6.8	9.0	2.2
Hulls	17	4	4.61	5.26	8.2	17.0	8.8
Gypsum	18	4	4.61	5.12	7.8	17.0	9.2
Raw rock	19	4	4.61	6.24	9.5	21.0	11.5
Control	20	4	4.61	5.38	7.2	11.5	4.3
Molashcake	21	5	4.78	6.53	7.5	9.0	1.5
Hulls	22	5	4.78	4.95	9.0	20.0	11.0
Gypsum	23	5	4.78	4.85	8.5	13.0	4.5
Raw rock	24	5	4.78	5.73	9.8	23.5	13.7
Control	25	5	4.78	5.00	6.0	12.5	5.5
Molashcake	26	6	4.97	6.12	6.5	9.5	3.0
Hulls	27	6	4.97	4.72	9.3	17.0	7.7
Gypsum	28	6	4.97	4.77	8.0	12.5	4.5
Raw rock	29	6	4.97	5.70	9.8	21.0	11.2
Control	30	6	4.97	4.94	6.8	13.0	6.2
Molashcake	31	7	4.83	6.14	6.5	12.0	5.5
Hulls	32	7	4.83	4.65	10.8	21.0	10.2
Gypsum	33	7	4.83	4.73	7.3	12.5	5.2
Raw rock	34	7	4.83	5.39	9.0	22.0	13.0
Control	35	7	4.83	4.43	6.8	9.0	2.2
Molashcake	36	8	4.67	6.34	7.4	14.0	6.6
Hulls	37	8	4.67	4.83	9.0	19.5	10.5
Gypsum	38	8	4.67	4.67	9.0	13.0	4.0
Raw rock	39	8	4.67	5.56	11.5	23.0	11.5
Control	40	8	4.67	4.85	6.0	9.0	3.0
Molashcake	41	9	6.41	6.71	7.0	12.5	4.5
Hulls	42	9	6.41	5.00	7.0	18.0	11.0
Gypsum	43	9	6.41	4.87	8.8	17.5	8.7
Raw rock	44	9	6.41	5.50	8.8	18.0	9.2
Control	45	9	6.41	5.05	4.7	10.0	5.3
Molashcake	46	10	5.95	6.02	9.3	17.0	7.7
Hulls	47	10	5.95	4.73	9.8	22.0	12.2
Gypsum	48	10	5.95	4.85	8.5	18.0	9.5
Raw rock	49	10	5.95	5.80	9.5	21.0	11.5
Control	50	10	5.95	5.14	6.5	9.0	2.5

Soil Type 1

Molashcake Rice Hulls Gypsum Raw Rock Phosphate Control

Soil Type 2

Molashcake Rice Hulls Gypsum Raw Rock Phosphate Control

Soil Type 3

Molasheake | Rice Hulls | Gypsum | Raw Rock Phosphate | Control

Soil Type 4

Molashcake | Rice Hulls | Gypsum | Raw Rock Phosphate | Control

Soil Type 5

Molashcake | Rice Hulls | Gypsum | Raw Rock Phosphate | Control

Soil Type 6

Molashcake | Rice Hulls | Gypsum | Raw Rock Phosphate | Control

Soil Type 7

Molashcake	Rice Hulls	Gypsum	Raw Rock Phosphate	Control

Soil Type 8

Molashcake	Rice Hulls	Gypsum	Raw Rock Phosphate	Control

Soil Type 9

Molashcake | Rice Hulls | Gypsum | Raw Rock Phosphate | Control

Soil Type 10

Molashcake | Rice Hulls | Gypsum | Raw Rock Phosphate | Control

Experiments Concerning the Preservation of Cane Stalks and Tassels

By E. D. Roberts

In order to throw light on certain doubtful points, experiments were started last August with a view of establishing a permanent practice of keeping cane stalks with their tassels alive long enough to give them time to become fertilized and ripen-off. Since tasseling stalks were unobtainable at that time, the work was begun with growing stalks, on the assumption that the reactions of the two types of stalks toward the solutions in which they are kept would be similar. By and large, this assumption held true, but as will be seen later, in a few instances exceptions to this rule were noticed.

This work was, of course, based directly upon the successful investigations of the agricultural department of the Experiment Station (1), (2), (3), (4), (5), W. Twigg-Smith (6) and F. E. Hance (7). There were, however, a few factors and variables which it seemed desirable to investigate further before deciding on a permanent practice and routine.

Furthermore, it was thought worth while to look for a chemical which would do as well or better than the sulphurous acid solution had done, because in using such a substance the labor entailed in changing solutions (to keep up their strength and prevent oxidation) would be considerably reduced.

Another question was whether the inexpensive and easily obtainable soy tubs could be used as containers for preserving the stalks without damage to them. It was also felt that if more were known about the process of absorption going on within the plant, about the actual amount of inorganic acids taken up, it would be an aid in the problems concerning the preservation itself. In order to determine whether the minute amounts of acid, if taken up, would keep the plant alive, but injure the viability of the pollen, experiments were started to supplement and apply the work of D. M. Weller (8).

It was believed that if these and several other points were experimented with and their importance to actual practice found, they would probably have bearings on the routine of crossing varieties and be perhaps applicable on a large scale.

Finally it was felt that it would be interesting to find out whether the life of stalks or tassels could be prolonged, or at least its vitality enhanced by adding nutrients in one or the other form or manner to the canes to be preserved.

Before beginning the experiments with the stalks themselves it was thought advisable to become more closely acquainted with the variables which might be introduced by the solutions. These would naturally fall into three categories:

(1) The composition of the gas as received in the cylinders (its purity and stability).

(2) The accuracy that was obtained with the method used to saturate the water with SO_2 gas; to establish the range of error, if any, and to ascertain the effect on the cane preserved with them.

(3) To observe and note the effect of changes which the solutions would undergo after the material to be preserved was placed in the solution; to find, if possible, means to control these changes, in case it were found that they were detrimental to the preservation of the stalks.

It was practically certain that smaller or greater amounts of SO_3 gas would be present in the commercial SO_2 gas at our disposal, and as it was believed that H_2SO_4 would be toxic to the cane, the first experiments were started with a view of eliminating these. Six samples of gas were analyzed according to the method practiced in the sulphitation process in Java sugar factories (Tervooren*), and the relative contents of SO_2 and SO_3 resulted, as shown in Table I. Some of these cylinders contained resublimed sulphur in very small quantities.

The methods in use when these experiments were started for obtaining a 3 per cent sulphurous acid solution consisted in placing a tared bottle containing 1940 gms. of water on one side of a balance and placing 2000 gms. plus the weight of the container on the other side. Then the gas was bubbled through until it tipped the balance. Due to the high volatility of such a solution, the results were invariably below 3 per cent. Table IV gives the results of analyses made to determine by titration the actual strength of 20 solutions made in the above manner. The range of variation was about 0.5 per cent, with the lowest being 2.31 per cent and the highest 2.84 per cent. Subsequent analyses of solutions made from other cylinders gave somewhat higher results. The method for titration used was: The SO_2 solution was diluted 10 times (if above 1 per cent) and placed in a burette. A few drops of a soluble starch solution were added to 10 ml. of a N/10 iodine solution† and the sulphurous solution added until the blue color disappeared. Each ml. of the sulphurous solution used had to be divided into 32 in order to obtain the strength of SO_2 in per cent.

At the suggestion of F. Hansson, the titrations were every now and then repeated with the potassium bichromate method in order to check the strength of the iodine solution. Here to 10 cc. of a N/10 potassium bichromate solution a few grams potassium iodide were added, the solution was acidified with HCl and titrated against a 10 times diluted H_2SO_3 solution until the color faded. Then a few drops freshly prepared soluble starch solution were added and titrated to the end point. Here too, 32 has to be divided by the number of ml. dilute sulphurous acid used to obtain the percentage of H_2SO_3.

As it was believed that the presence of SO_3 was decidedly harmful to the plant it had been the custom to lead the gas through a washbottle before saturating the water. Later on, this method was abandoned (W. Twigg-Smith) (6). Table

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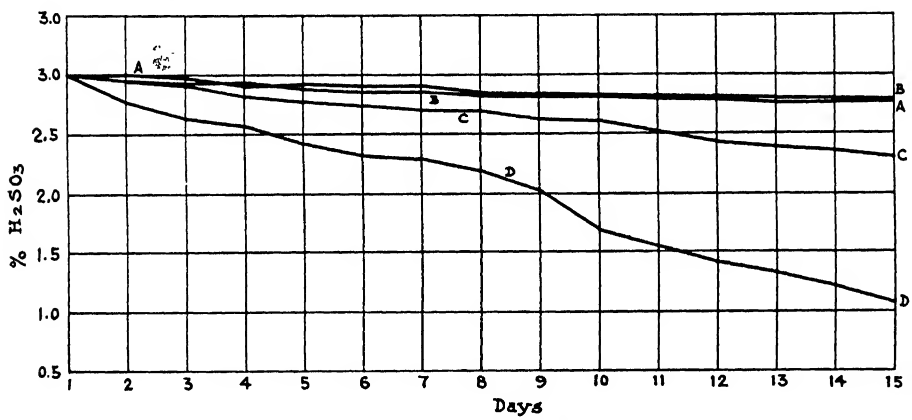
* Handboek voor de Suikerriet-Cultuur en de Rietsuiker-fabricage op Java. Deel 1, 4eDruk. p. 282.

† N/10 iodine solution is prepared by adding to 12.7 gms. iodine crystals, 50 gms. potassium iodide and 200 ml. water. After the iodine has dissolved, make up to 1000 ml. and mix. Keep in dark bottle in dark place. The starch solution is made by rubbing in a mortar 2 gms. soluble (or 5 grams ordinary starch) with 10 gms. mercuric iodide and with water to a thin liquid, this liquid is added to a liter of boiling water. This starch solution will keep indefinitely. (Tervooren, loc. cit., pp. 170, 350.)

II and Table III, as well as the accompanying graph, show the effect on the SO_3 content when the SO_2 was washed. They also confirm the suspicion that the solution would oxidize and the SO_3 content increase. The result of washing was to reduce the SO_3 content very considerably. Even so, it was rather high if compared with later results (Table VI, for instance) when better gas had been obtained. The use of barium chloride to precipitate the SO_3 as sulphates was unsuccessful, as it was almost completely used up to form barium sulphite with the SO_2, after which the old situation prevailed. While no experiments proved conclusively that stalks lived better in solutions with a low SO_3 content, it was certain that they were not worse off if the gas was washed. The cause for this is probably that oxidation takes place and increases the SO_3 content more rapidly in the washed than in the unwashed solutions. Accordingly, washed sulphurous was used for the whole seedling season.

Decrease of SO_2 concentration in various containers



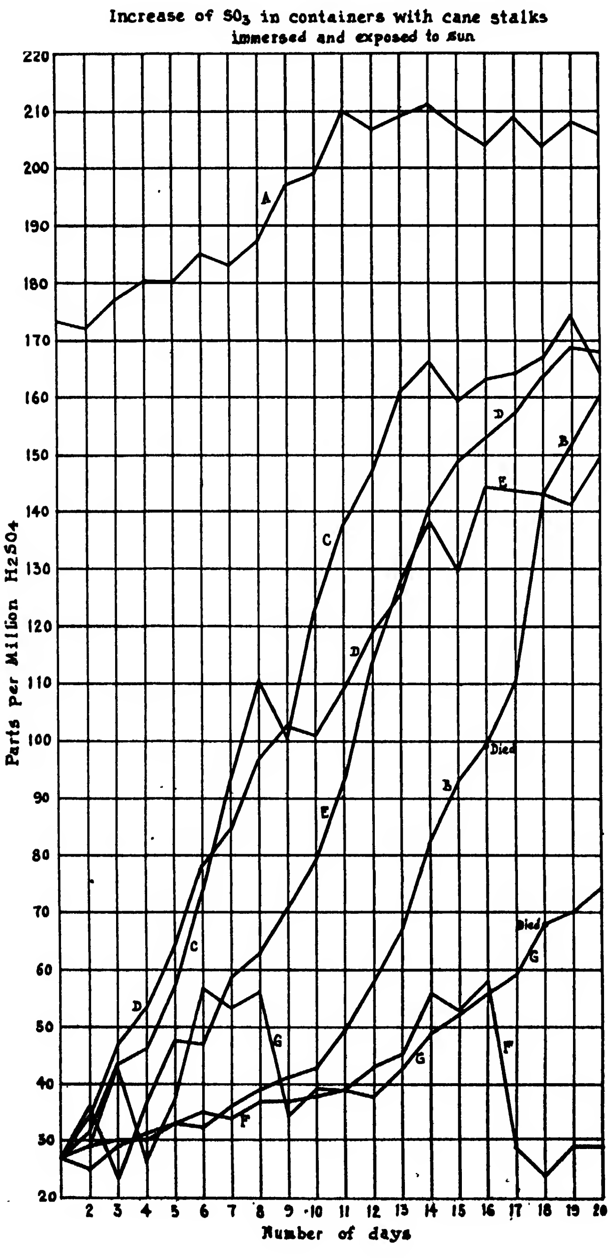
A. Averages of 6 bttls. Amber
B. " " " " Clear Kept on Ice
C. " " " " Clear Kept in Laboratory
D " " " " Exposed to Sun (clear)

The next question was as to how the solution should be kept before actually using. During the seedling season, up to 60 liters stock solution (3 per cent) was used daily and during the rainy days even more. It was imperative to ascertain in which containers the concentration required would be best maintained. For that purpose, six 4-liter bottles, each of the following type, were filled with the titrated solution and analyzed daily for 15 successive days: (1) Clear bottles placed at an arbitrary point within the laboratory, (2) clear bottles kept on ice, (3) clear bottles kept in sunlight, (4) amber bottles kept in laboratory. As can be seen in Table V, the result clearly indicated that the smallest amount of deterioration was noticed in the bottles kept on ice, while the solutions kept in amber bottles and out of sunlight ran a very close second. As had been anticipated, the solution in the clear bottles in the laboratory, and especially in the sun, lost their strength very rapidly. Thus, for the remainder of the season, the solutions were kept in amber bottles as far as feasible. When the season was at its height, not enough amber bottles of this size could be procured locally and clear

bottles were used, but it was endeavored to keep them on ice until immediately before consumption.

As the usual gravimetric determination was too cumbersome (weighing as barium sulphate) the turbidimetric method as practiced for water analysis was adopted at the suggestion of W. T. McGeorge, who together with C. W. Nesbitt and L. E. Davis obliged the writer on several occasions by running check analyses.

This method consisted in placing 50 ml. of the solution to be compared into a glass stoppered bottle, adding 1-2 drops of HCl, and 0.1 to 0.2 g. barium chloride



All figures are calculated back to original concentration (A, B, C, D etc. × 100)

A. Unwashed $\frac{2\%}{100}$ Solution
B. Washed $\frac{3\%}{100}$ Solution with 0.1% C_2H_5OH
C. Washed $\frac{3\%}{100}$ Sol. in painted wooden container
D. Washed $\frac{3\%}{100}$ Sol. in unpainted wooden container
E. Washed $\frac{3\%}{100}$ Sol. in Glass Jar
F. Washed $\frac{3\%}{100}$ Sol. in Glass Jar solution changed daily
G. Washed $\frac{3\%}{100}$ Sol. in crock with 0.08% $SnCl_2 + 2H_2O$

SO_2 Content after 20 ds.

A	.0092 %
B	.0112 %
C	.0096
D	.0091
E	.0134
F	.0310
G	.0221

(precipitation in the cold) and turbidimetrically comparing with a standard suspension of barium sulphate. The experiments tabulated in Tables VI, VII and VIII are largely self-explanatory and shall be discussed only briefly. The variables here were containers, cuttings joints against no cutting, negative (retarding catalysts) changing solutions against refilling the amount of solution absorbed or evaporated, strength of solution, placing stalks into the solution immediately after cutting, and short as against long stalks.

As far as the containers were concerned, glass jars were the best. The reason for this is probably that one single stalk per container made for better survival. Whenever dying stalks were removed from the tubs and the solutions changed, the rest of the stalks kept on living. Stone crocks were not better than wooden soy tubs, especially after C. G. Lennox had coated the latter with asphalt during the seedling season. They were then quite satisfactory.

While these experiments were going on, a sample of the solution from each container was analyzed daily and it could be ascertained at what rate the SO_2 was oxidizing into SO_3.

This oxidation took place till a certain limit was reached, which apparently caused many of the plants to die. Several means were tried to check this oxidation. Holleman* mentions 0.1 per cent alcohol and 0.08 per cent stannous chloride as retarding catalysts. These were tried, but were found to kill the plant in spite of the fact that the oxidation was greatly decreased.

Sodium hydrosulphite, sold under the name of Blankit, was tried as a substitute for SO_2 gas. The results on stalks compared with the best obtained with SO_2, but on tassels it did not quite come up to the standard set by SO_2 gas. The experiments with tassels were not conclusive in that respect. A certain amount of Blankit was weighed, dissolved in water, titrated for its SO_2 content and made up to a strength of 3 per cent SO_2. Later on, this stock solution was diluted 100 times just as the other solution was (about 60 gm. Blankit per liter would make a 3 per cent solution). Sodium nitrite solution as described by F. E. Hance† was mixed in equal parts with SO_2 solution and very encouraging results were obtained. A. J. Mangelsdorf, especially, succeeded in obtaining very good results with these combined solutions, while with Blankit he did not obtain as good results as with nitrite.

After tassels were obtainable, all experiments were carried out with them and germinations were counted. Only one experiment could, however, be completed successfully, because bad weather set in and introduced so many upsetting variables (breaking-off of tassels, diluting solutions, destroying pollen, causing premature harvesting), that only few germinations were obtained. In Table X, an experiment of 26 crosses of the same parentage is computed. The conclusions are obvious; cutting joints and changing solutions proved to be most desirable, especially in conjunction. Cutting joints once a week, together with a changing of the solution every 3 days proved to be sufficient. Tassels crossed in the absence of

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* Textbook of Inorganic Chemistry. A. F. Holleman, John Wiley and Sons, 1921.

† Nitrite solution: 70 grams sodium nitrite dissolved in 1 liter of water, 25 ml. conc. H_2SO_4 added. Ten ml. of this solution were diluted to 1 liter with tap water and constitutes the nitrite solution mentioned. (*Hawaiian Planters' Record*, 1927, Vol. XXXI, p. 363.)

5. Cutting joints once a week and changing solutions every three days seemed the best means of keeping stalks over a long period.

6. Protection from wind was found to prolong the life of stalks.

7. While single-stalk jars were the best containers, soy tubs were satisfactory if solutions were changed as under 5, especially after an asphalt coating had been applied. A. J. Mangelsdorf feels that the asphalt-coated soy tubs did as well as any other container for his main work.

8. Placing stalks immediately into sulphurous acid solutions after the stalks had been cut did not show any advantages against the method in use; i.e. keeping the stalks in water while carrying them to the crossing station.

9. While the writer's experiments pointed in favor of medium length of stalks and stripping of leaves, no definite conclusions could be made, as many stalks, where the leaves had been left on, kept very well.

10. While Blankit proved to be a good preserver of stalks, it is not improbable that the sodium introduced in that manner made for more rapid drying of tassels, in spite of the very small amount of oxidation taking place in a solution of this salt. Even so, quite a number of good germinations in the writer's experiments were obtained with its help.

11. All the other experiments carried out (where on account of bad weather no definite conclusions had been possible) were carried on with Blankit and proved:

a. That cutting and changing, as under 5, was essential.

b. That ripening off should be carried out as long as possible with access to sun.

c. That even though germinations were obtained when tassels were harvested before 19 days had elapsed (15 and 16 days respectively), by and large 19 days seemed to be the minimum (Table XII).

12. The only effect that could be surely ascertained as a consequence of nutrient solutions was an abundant growth of auxiliary roots.

Absorption Experiments

Successive joints of stalks were analyzed for their SO_2 content and as shown in Table XI it was found that in 3 out of 15 instances minute amounts (0.001 per cent) had reached the joint below the highest after 38 days. Fifteen stalks out of the 30 under observation flowered after more than 40 days had elapsed, and in the 3 instances where traces of SO_2 had reached the highest joint the pollen was absolutely dry, and when examined under the microscope showed no reaction after the iodine test had been applied. In 8 cases of the 12 remaining ones, where the highest joints were not found to contain any SO_2, most of the pollen showed a regular shape and gave a reaction to the iodine test.

Twelve tassels were cut above the highest joint and placed in jars and pollen was collected daily. The result was that after the third day no more viable pollen could be found, and that after the fourth day most ovules and stigmas looked dry and seemingly had lost all vitality. The check samples placed in water showed that at least 6 days were required before all the pollen had lost its viability and about 8 days to give the ovules and stigmas a dried appearance.

If one joint was left on the tassel the effect was the same, only that it took two days longer on the average to produce this effect. The conclusions of the writer are as follows:

In no single instance was it found that sulphurous acid or any of its substitutes had reached even the joint below the highest when the stalk had been immersed for less than 38 days, provided that a minimum of 10 joints was left on the stalk when the experiment was started and not more than one joint was cut every week. Accordingly there seems to be conclusive evidence that under the present practice any direct toxic effect of SO_2 on viability of pollen or ovules and thus on germination is impossible, as even in the most extreme cases only 35 days are required from the day the crossing is started until the fuzz is planted. As a consequence, if the tassel and stalk are kept living for these periods, germination will not be decreased on account of a direct influence of sulphurous acid.

LITERATURE CITED

(1) Das, U. K. 1925. Experiments to Keep Cut Tassels Alive. Proj. File 489.70.

(2) Verret, J. A., in collaboration with Kutsunai, Y., Das, U. K., Conant, R., and Twigg-Smith, W. 1925. A Method of Handling Cane Tassels for Breeding Work. Hawaiian Planters' Record. Vol. XXIX, pp. 84-94.

(3) Das, U. K., and Wilder, J. A. H. 1926. The Sulphurous Acid Method of Preserving Cane Tassels. Repts. of the Association of Hawaiian Sugar Technologists. pp. 65-67.

(4) Das, U. K. 1927. Experiments to Keep Tassels Alive. Part 2, Proj. File 489.70.

(5) Verret, J. A., Mangelsdorf, A. J., Lennox, C. G. 1927. On Preserving Cane Stalks. Hawaiian Planters' Record, pp. 331-335.

(6) Twigg-Smith, W. 1925-1926. Memoranda and Notes. Proj. File 489.70.

(7) Hance, F. E. 1927. The Preservation of Cane after Cutting from the Stool. Hawaiian Planters' Record. Vol. XXXI, pp. 362-367.

(8) Weller, D. M. 1926. Progress Report of Sugar Cane Pollen Studies. Hawaiian Planters' Record. Vol. XXX, pp. 400-414.

TABLE I

CONTENT OF SO_2, SO_3, AND S IN 100 cc. OF COMMERCIAL SO_2 GAS

Sample	SO_2	SO_3	S
1	96.02	3.26	0.3
2	94.71	4.20	...
3	98.23	1.33	...
4	93.20	4.67	0.7
5	91.30	7.28	0.2
6	97.56	2.10	...

TABLE II

UNWASHED SULPHUROUS ACID SOLUTION

IMMEDIATELY AFTER MAKING		THE SAME AFTER 4 WEEKS	
15 Samples Each Made Up To % H_2SO_3	P. P. M. H_2SO_4 Average	Per Cent H_2SO_3	P. P. M. H_2SO_4 Average
1	165	0.6	185
2	300	1.3	325
3	360	2.1	375
4	390	2.9	420
5	490	3.4	525
6	610	4.0	635
7	685	4.6	730
8	740	4.8	790
8.5	795	5.2	855

TABLE III

WASHED SOLUTION

IMMEDIATELY AFTER MAKING				AFTER 4 WEEKS			
	Parts per Million			Parts per Million			
15 Samples Each Made Up To % H_2SO_3	H_2SO_4 Average	H_2SO_4 High	H_2SO_4 Low	15 Samples Each H_2SO_3	H_2SO_4 Average	H_2SO_4 High	H_2SO_4 Low
1	90	100	70	0.3	130	150	115
1.5	115	120	110	0.5	145	155	130
2.0	80	140	45	0.8	140	160	125
2.5	145	160	125	1.8	165	175	150
3.0	160	170	155	2.1	200	220	175
3.5	180	205	160	2.5	210	235	200
4.0	230	240	220	2.7	250	275	225
4.5	220	235	210	3.3	240	280	215
5.0	260	285	245	4.0	270	300	245
5.5	280	305	260	4.2	300	320	275
6.0	290	305	270	4.5	325	345	300
6.5	340	365	325	4.9	390	420	365
7.0	335	365	320	5.0	450	485	410
7.5	375	405	345	4.9	510	520	495
8.0	390	410	380	5.2	500	530	490
8.5	405	420	400	5.4	780	898	640

TABLE IV

20 SAMPLES 3% H_2SO_3 MADE BY WEIGHING METHOD

Sample	% Found by Titrating	Sample	% Found by Titrating
1	2.63	11	2.47
2	2.68	12	2.81
3	2.42	13	2.54
4	2.31	14	2.39
5	2.57	15	2.76
6	2.73	16	2.64
7	2.45	17	2.80
8	2.34	18	2.43
9	2.79	19	2.81
10	2.80	20	2.55

TABLE V

AVERAGES OF DAILY ANALYSES OF SIX BOTTLES EACH OF A 3.01% H_2SO_3 SOLUTION

Day	Amber Bottles	Clear Bottles Kept on Ice	Clear Bottles	Amber Bottles in Sunlight
1st	3.01	3.01	3.01	3.01
2nd	2.95	3.00	2.95	2.76
3rd	2.93	2.97	2.91	2.63
4th	2.94	2.92	2.80	2.57
5th	2.90	2.91	2.76	2.41
6th	2.87	2.90	2.74	2.32
7th	2.85	2.90	2.70	2.29
8th	2.82	2.83	2.69	2.18
9th	2.82	2.82	2.63	2.03
10th	2.80	2.81	2.61	1.67
11th	2.81	2.81	2.52	1.54
12th	2.79	2.79	2.43	1.40
13th	2.78	2.80	2.39	1.33
14th	2.78	2.79	2.36	1.22
15th	2.76	2.78	2.30	1.08

TABLE VI

INCREASE OF H_2SO_4 IN P. P. M. WITH 4 STALKS EACH (EXCEPT WHERE NOTED) IMMERSED IN H_2SO_3 SOLUTIONS WITH DIFFERENT VARIABLES AS TO CONTAINER, SOLUTION, ETC.*

Day	Unwashed .02% Sol. in Soy Tubs. Unpainted.	Washed .03% Sol. Painted Soy Tubs. .1% C_2H_5OH.	Washed .03% Sol. Painted Soy Tubs.	Washed .03% Sol. in Soy Tubs. Unpainted.	Washed .03% Sol. Glass Jars. Single Stalks.	Washed .03% Sol. Glass Jars. Changed Solution Daily.	Washed .03% Sol. Stone Crocks With Stannous Chloride .08%.
1st	173	27	27	27	27	27	27
2nd	172	25	29	34	36	31	29
3rd	177	29	43	47	23	43	30
4th	180	31	46	53	37	26	30
5th	180	33	57	64	48	37	33
6th	185	32	74	78	47	57	35
7th	183	36	93	75	59	53	34
8th	187	39	110	97	63	56	37
9th	197	41	100	103	71	34	37
10th	199	43	123	101	79	39	38
11th	210	49	138	109	93	39	39
12th	207	58	147	119	114	43	38
13th	209	67	161	126	127	45	42
14th	211	82	166	141	138	56	49
15th	207	93	159	149	129	53	52
16th	204	99+	163	153	144	58	56
17th	209	110	164	157	157	29	59
18th	204	142	167	164	143	24	68+
19th	208	151	174	169	141	29	70
20th	206	160	164	168	149	29	74
% H_2SO_3 After 20 Days	.0092	.0112	.0096	.0091	.0134	.0310	.0221
Condition of Stalks	Bad	Dead at 16th day	Bad	Bad	Medium to Bad	Excellent	Died on 18th day
	A	B	C	D	E	F	G

* The figures for SO_3 refer to original concentration and thus should be divided by 100.

TABLE VII

FIRST ELIMINATION EXPERIMENT

	Painted Soy Tubs. (With Petroloid)	Unpainted Soy Tubs.	Stone Jars.	Glass Jars.	Immersed in Sol. in Field Immediately After Cutting.	0.1% C_2H_5OH.	Blankit to .03% SO_2	Changed Sol. Daily.	Cut Joints Once a Week.	Growing Auxiliary Roots.	Cut Once a Week; Unwashed Sol. Glass Jars.	Washed; Inside Greenhouse, Stannous Chloride; Stone Crocks	Sodium Nitrite Mixed With H_2SO_3
						After 28 Days.							
Dead	7	5	6	5	6	6	4	.	.	8	9	4	5
Living	5	6	6	12	6	.	7	8	8	.	19	2	7
						After 42 Days.							
Dead	12	11	9	8	8	6	4	.	2	8	14	4	7
Living	..	..	3	9	4	.	7	8	6	.	14	1	5
						After 56 Days.							
Dead	12	11	12	12	11	6	5	2	3	8	20	4 '	9
Living	..	..	..	5	1	.	6*	5†	5	.	8	1‡	3§

TABLE VIII

SECOND ELIMINATION EXPERIMENT—50 DAYS

All in painted (lacquered) soy tubs, 4 stalks per tub.

	SOLUTION NOT CHANGED				SOLUTION CHANGED DAILY			
	Cut Joints		Joints Not Cut		Cut Joints		Joints Not Cut	
	Dead	Living	Dead	Living	Dead	Living	Dead	Living
				After 30 Days.				
.02%	..	‖2 (=+)	1	1 (—)	..	2 (++)	..	2 (==)
.03%	..	2 (++)	1	1 (—)	..	2 (++)	..	2 (=—)
.04%	..	2 (=+)	..	2 (——)	.	2 (++)	..	2 (——)
				After 50 Days.				
.02%	..	2 (=+)	2	....	..	2 (+=)	1	1 (—)
.03%	..	2 (=+)	2	....	..	2 (++)	..	2 (——)
.04%	..	2 (==)	2	....	..	2 (+=)	1	1 (=)

SUMMARY AFTER 60 DAYS

75 % of stalks living, change 2% solution daily, cut joints twice a week.
87.5% " " " " 3% " " " " " " "
75 % " " " " 4% " " " " " " "
25 % " " " " 2% " " no cutting of joints.
50 % " " " " 3% " " " " " "
37.5% " " " " 4% " " " " " "
62.5% " " " no changing of 2% solution, cut joints twice a week.
62.5% " " " " " " 3% " " " " " "
50.0% " " " " " " 4% " " " " " "
....% " " " " " " 2% solution, no cutting of joints.
....% " " " " " " 3% " " "
....% " " " " " " 4% " " "

* 2 Stalks started flowering after 43 and 45 days respectively. Shed pollen after 48 days and 49 days respectively.

† 2 Stalks started flowering after 48 days.
1 Stalk shed pollen after 53 days, was selfed, one germination after 72 days.

‡ 1 Stalk flowering after 54 days, shed pollen after 61 days.

§ 1 Stalk started flowering after 30 days; no pollen.

‖ Figures refer to tubs as a whole (with 4 stalks each).

TABLE IX

COMPARISON BETWEEN SODIUM HYDROSULPHITE (BLANKIT) AND SULPHUROUS ACID AS TO THEIR LOSS OF STRENGTH AND OXIDATION

	BLANKIT TO 3% SO_2		H_2SO_3 3%	
	SO_2	SO_3	SO_2	SO_3
1	3.02	..	3.03	38
2	3.00	..	2.97	42
3	2.96	..	2.89	49
4	2.90	25	2.86	47
5	2.86	27	2.80	52
6	2.82	29	2.70	60
7	2.79	28	2.64	63
8	2.72	30	2.62	68
9	2.68	30	2.47	74
10	2.65	32	2.40	82
11	2.63	31	2.33	86
12	2.62	32	2.27	90
13	2.61	33	2.17	93
14	2.61	34	2.09	99
15	2.59	34	2.00	101
16	2.60	35	1.89	123
17	2.56	35	1.80	134
18	2.54	36	1.72	138
19	2.55	36	1.64	146
20	2.54	36	1.53	159
30	2.41	41	1.15	176

TABLE X

26 LAHAINA X D 1135 CROSSES COMPLETED UNDER FAVORABLE WEATHER CONDITIONS, STARTED NOVEMBER 7

No. of Cross.	Location.	Remarks.	Date Planted.	Condition of Tassel at End of Experiment.	Condition of Stalk at End of Experiment.	Condition of Male Tassel.	Strength of Solution.	Solution Changed	Joints Cut.	Container.	Germination.	Survival Per Cent.	Condition March 1.
1	Under roof	A	Nov. 26th	=	=	=	.03%	No	No	Glass Jar	None	.....	.....
2	" "	A	"	=	=	dead	.03%	"	Twice a week	"	"	.....	.....
3	" "	A	"	+	+	=	.03%	Daily	" "	"	"	.....	.....
4	" "	A	"	=	=	=	.03%	"	No	"	"	.....	.....
5	" "	A	"	—	—	—	.03%	No	"	"	"	.....	.....
6	" "	A	"	—	=	=	.03%	"	Twice a week	"	"	.....	.....
7	" "	A	"	=	=	=	.03%	Daily	" "	"	"	.....	.....
8	" "	A	"	=	=	+	.03%	"	No	"	"	.....	.....
9	No Protection	A	"	=	=	=	.03%	No	Twice a week	"	10	100%	Fair
10	" "	A½	"	+	=	=	.015%	"	" "	"	None	.....	.....
11	" "	A	"	+	+	=	.03%	"	" "	"	4	100%	Fair
12	" "	A½	"	=	=	=	.015%	"	" "	"	2	50%	Good
13	" "	A	"	=	=	=	.03%	"	" "	"	400	100%	Excellent
14	" "	A½	"	+	+	+	.015%	"	" "	"	None	.....	.....
15	" "	A	"	—	—	—	.03%	"	No	"	"	.....	.....
16	" "	A	"	—	=	—	.03%	Daily	"	"	44	85%	Fair
17	" "	A	"	—	=	—	.03%	No	"	"	None	.....	.....
18	" "	A	"	—	—	—	.03%	Daily	"	"	"	.....	.....
19	" "	B	"	+	=	=	Blankit	"	Twice a week	"	20	100%	Good
20	" "	B	"	=	=	—	"	No	" "	"	2	.....	.....
21	" "	B	"	=	=	+	"	"	No	"	None	.....	.....
22	" "	B	"	=	+	=	"	Daily	Twice a week	"	10	100%	Fair
23	" "	C	"	=	=	+	Nitrite + H_2SO_3	"	No	"	11	48%	Good
24	" "	B*	"	+	+	+	Blankit	"	Twice a week	"	50	100%	Good
25	" "	C*	"	+	+	=	Nitrite + H_2SO_3	"	" "	"	8	100%	Good
26	" "	B*	"	=	=	=	Blankit	"	" "	"	10	100%	Good

A=Washed H_2SO_3 solution.
A½="A" solution half strength.
B=Blankit solution to .03% H_2SO_3 concentration.
C=Fifty per cent .03% H_2SO_3 solution, and 50 per cent sodium nitrite solution as per insertion in text.

* These tassels were left 3 hours out of solution after being cut.

TABLE XI

PARTS PER MILLION OF SO_2 IN CANE JUICE OF STALKS IMMERSED IN .03% SO_2 SOLUTION

After:	10th Joint (From Top)	9th Joint	8th Joint	7th Joint	6th Joint	5th Joint	4th Joint	3rd Joint	2nd Joint	Top Joint
7 Days	80	12	..	..	..	..	..	..	..	..
14 "		72	8	..	..	..	..	..	..	..
21 "			65	10	5	..	..	..	..	..
28 "				70	15	3	..	..	..	..
35 "					66	10	5	..	..	..
38 "						78	15	8	..	..
43 "							59	18	3	..
48 "								82	15	6
50 "									74	20

TABLE XII

FURTHER GERMINATIONS OBTAINED AND THEIR TREATMENT

Number	Parentage	Started	Planted	Cut Joints	Sol. Changed	Type Solution	Length Stalk	Length Leaves	Germination	Survival	Condition Mar. 1
30	Y. T. x Paia 186	Nov. 14	Nov. 26	No	Yes	Blankit	short	short	15	100%	Good } 1
38	Y. T. x Paia186	" "	" "	"	"	"	long	long	2	100%	Fair } 1
54	Y. T. x Paia 186	" 15	" 29	Yes	"	"	long	short	9	.....	....
61	H 109 Self	Sept. 17	" 20	3 times	"	"	long	short	1	.....	 2
65	Wh. Bamboo x 1923 E543	Nov. 30	Dec. 18	No	"	"	long	short	1	100%	Fair 3
68	Striped Mex. x 8965	" "	" "	Yes	"	"	long	long	4	100%	Fair
69	S. W. 3 Self	Dec. 12	" 16	"	"	"	short	short	35	100%	Good 4
67	Striped Mex. x Paia F	Nov. 20	Dec. 12	"	"	"	long	short	10	.....	....
80	P. O. J. 2221 x 25 C 4	Dec. 6	" 27	"	"	"	long	long	1	100%	? } 5
85	Lah. x S. W. 3	" "	" "	"	"	"	long	long	2	.....	.... } 6
86	Y. T. x S. W. 3	" "	" "	"	"	"	long	long	9	100%	Good } 6

1 Only germinations obtained from 14 crosses prematurely harvested on account of weather.
2 This stalk had tasseled 54 days after placing in solution.
3 Only germination obtained from 7 crosses prematurely harvested.
4 When collected in field nearly dry.
5 Could not be located on March 1.
6 Only germinations from 16 crosses prematurely harvested, broken by storm, etc.

Sugar Prices

96° Centrifugals for the Period March 19 to June 13, 1928

Date		Per Pound	Per Ton	Remarks
March	19, 1928.....	4.58¢	$91.60	Cubas.
"	21..........	4.55	91.00	Philippines.
"	22..........	4.52	90.40	Porto Ricos.
"	26..........	4.58	91.60	Cubas.
"	28..........	4.61	92.20	Cubas.
"	31..........	4.65	93.00	Cubas.
April	2..........	4.595	91.90	Porto Ricos, 4.58; Philippines, 4.61.
"	3..........	4.61	92.20	Philippines.
"	4..........	4.58	91.60	Porto Ricos.
"	5..........	4.52	90.40	Cubas.
"	10..........	4.49	89.80	Cubas, 4.52; Philippines, 4.46.
"	11..........	4.46	89.20	Cubas.
"	12..........	4.40	88.00	Philippines.
"	17..........	4.36	87.20	Porto Ricos.
"	19..........	4.43	88.60	Porto Ricos.
"	24..........	4.40	88.00	Cubas.
"	26..........	4.36	87.20	Philippines.
"	27..........	4.30	86.00	Porto Ricos.
May	2..........	4.43	88.60	Porto Ricos.
"	4..........	4.44	88.80	Porto Ricos, 4.40, 4.43; Cubas, 4.49.
"	8..........	4.40	88.00	Cubas.
"	10..........	4.46	89.20	Porto Ricos, 4.40; Cubas, 4.46, 4.52.
"	15..........	4.30	86.00	Porto Ricos.
"	17..........	4.38	87.60	Cubas, 4.36; Porto Ricos, 4.40.
"	18..........	4.505	90.10	Philippines, 4.49; Cubas, 4.52.
"	22..........	4.40	88.00	Porto Ricos.
"	24..........	4.49	89.80	Porto Ricos, 4.46; Cubas, 4.52.
"	25..........	4.46	89.20	Porto Ricos.
"	28..........	4.45	89.00	Cubas, 4.46; Philippines, 4.44.
June	1..........	4.36	87.20	Philippines.
"	4..........	4.315	86.30	Philippines, 4.33, 4.30.
"	5..........	4.285	85.70	Cubas, 4.30; Porto Ricos, 4.27.
"	11..........	4.30	86.00	Porto Ricos, 4.27; Cubas, 4.33.
"	12..........	4.285	85.70	Porto Ricos, 4.24; Cubas, 4.33.
"	13..........	4.21	84.20	Philippines.

THE HAWAIIAN PLANTERS' RECORD

Volume XXXII. OCTOBER, 1928 Number 4

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the Plantations of the Hawaiian Sugar Planters' Association.

Correspondence *The following letter dated August 9, 1928, was received from Mr. William Campsie, manager, Hutchinson Sugar Plantation Company:*

In looking over the article on "The Degree of Resistance and Susceptibility of Seedlings to Eye Spot" in last *Planters' Record,* we note that U. D. 1 is classed as being "more resistant than H 109."

It may interest you to know that we have found U. D. 1 to be extremely susceptible to eye spot on this plantation.

On January 25 of this year we wrote you regarding an outbreak of eye spot in one of our variety plots, at an elevation of 700 feet. U. D. 1 appeared to be the main source of infection in this case, and was affected to a much greater degree than any of the other varieties, quite a number of stools being killed off by the disease. The cane was mature at the time of the outbreak.

It is interesting to note that Paia F which was in direct contact with the U. D. 1 variety, was affected to a much less degree. We note that Paia F has an eye spot index of over 1000 as compared with 250-500 in the case of U. D. 1.

In August, 1927, we established a variety area in a field of D 1135, at an elevation of 2,100 feet. The varieties planted are as follows: U. D. 1, P. O. J. 979, P. O. J. 234, K 107, U. D. 5, Honokaa 1, U. D. 50 and K 202.

In February, 1928, eye spot was noted in the U. D. 1 and Honokaa 1 varieties. The attack was very slight at this date, and there was hope that the varieties would recover with the warmer weather. Instead of throwing off the disease, however, the outbreak has gradually increased, and at the present time a large part of the U. D. 1 variety has died.

As the outbreak is so severe, and the disease still spreading, we are left with no alternative, but to plow out the whole plot of U. D. 1 (about 3 acres).

Honokaa 1 is not so badly affected, but we shall plow this out also, and replant both areas with P. O. J. canes.

All the other varieties appear to be fairly resistant to eye spot. U. D. 5 has been affected, but to a slight degree. P. O. J. 213 is worthy of special mention, as this variety has escaped without a leaf blemish, although it is in direct contact with the U. D. 1 plot.

It is also of interest to note that we have a small plot of H 109 in another field at 1900 feet elevation, with almost the same climatic and soil conditions. A small

outbreak of eye spot was found in this variety in February, but the attack was slight, and the cane has now completely recovered.

U. D. 1 seems to be doing fairly well on other plantations, and we thought you would be interested to know that it is a complete failure here due to its susceptibility to eye spot.

Coptotermes Formosanus Shiraki in Bags of Sugar

The photograph (Fig. 1) shows the work of *Coptotermes formosanus,* the Hawaiian soil-nesting termite that was taken from one of five bags of sugar found infested with this insect on Pier 6, Honolulu. Fig. 2 shows sugar bags, from one of which this specimen was taken.

On August 23, we were notified that Captain Rasmussen, of the Matson Navigation Company, while loading sugar at Pier 6 aboard the S. S. "Lurline" located one bag, labeled "Nalo" sugar, infested with termites. Later, four more termite-ridden bags were found and all were placed in the pier office for inspection. We found no trace of the termite at the mill of the Waimanalo Sugar Company, whence the sugar had come, but a brief examination of the area on Pier 6, where the sugar had been piled up for about two weeks, showed *Coptotermes* present in small accumulations of soil on the floor near the gutter pipes, that furnished a certain amount of moisture, and in the woodwork there. Living termites were thus found on the waikiki side of the pier at a distance of at least 200 feet from the entrance to the pier, and abandoned work of these insects was

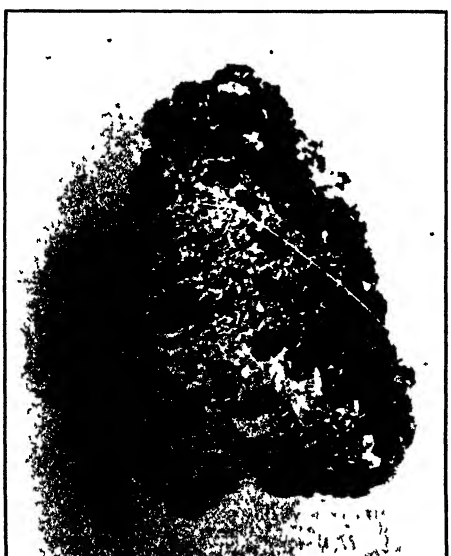


Fig. 1. Work of *Coptotermes formosanus.* Portion of earthy nest found in sugar bag. About natural size. (Photo by D. M. Weller.)

Fig. 2. Bags of sugar attacked by *Coptotermes formosanus.* (Reproduced through courtesy of E. M. Ehrhorn.)

apparent fully 100 feet beyond this, where conditions were drier. *Phidole megacephala* Fab., the common ant enemy of termites, was present in or about termite work. The termites eagerly availed themselves of the moisture of the sugar, biting through the bags where they were in contact with the floor and in several cases they accumulated in the bags themselves a considerable lump of soil as an extension of their nest, both soldiers and workers being found in abundance in the labyrinth of galleries in these moist soil lumps.

The remedy, of course, lies in the destruction of the termite colonies in and about the pier.

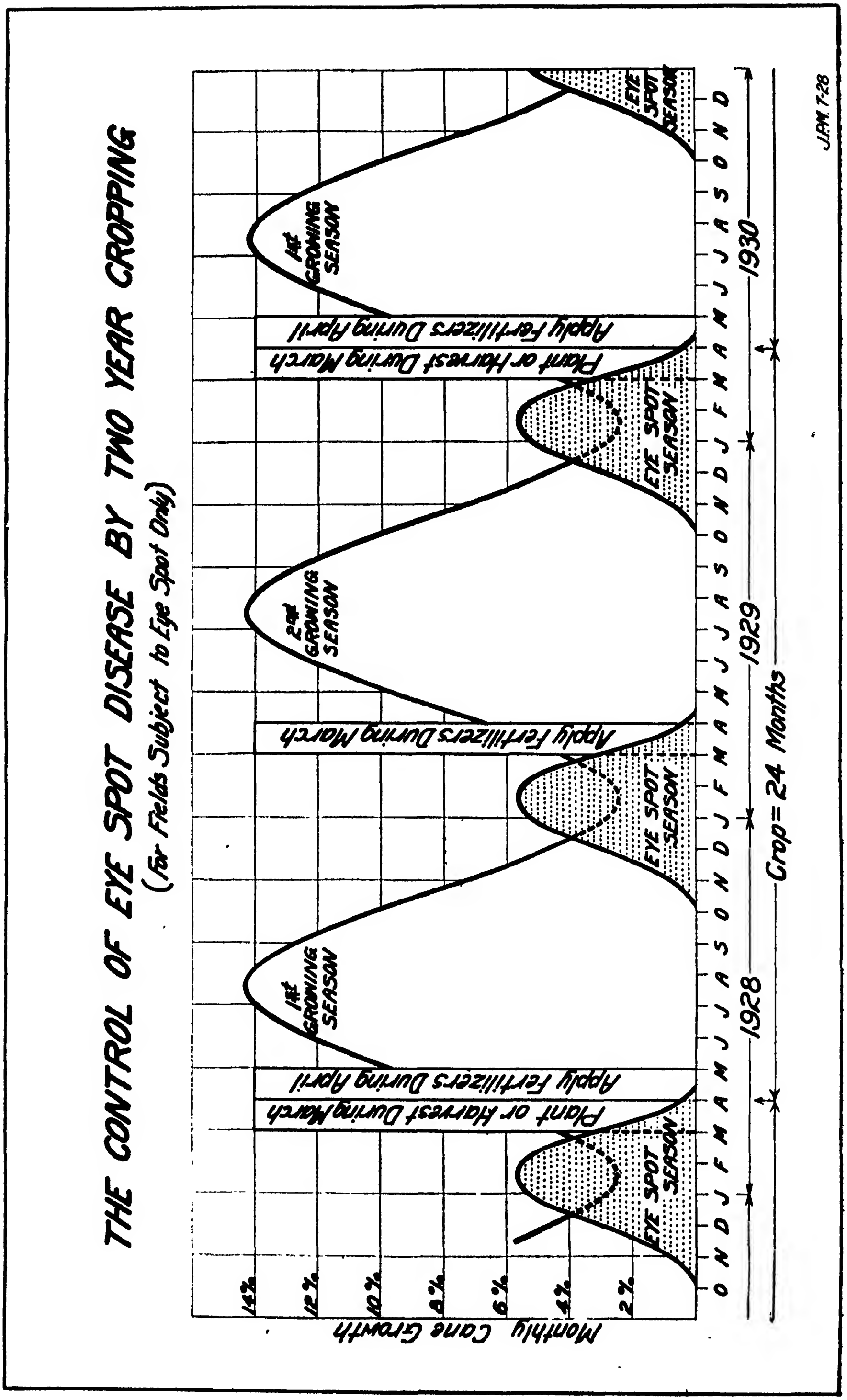
F. X. W.
R. H. V. Z.

The Control of Eye Spot Disease by Two-Year Cropping

By J. P. Martin

In the July *Record,* 1928, an article appeared on "Monthly Plantings of H 109 Cane in Relation to Eye Spot," by the writer. In this article the experimental results pointed out that the older H 109 cane is as it enters the eye spot season the more resistance the cane has to the disease. Numerous observations have confirmed these results wherein late planted or harvested cane in eye spot localities has always been more severely affected than early planted or harvested cane.

Eye spot generally appears in the same locality year after year because the environmental conditions are favorable for the development of the fungus in these


THE CONTROL OF EYE SPOT DISEASE BY TWO YEAR CROPPING
(For Fields Subject to Eye Spot Only)
Monthly Cane Growth
14%
12%
10%
8%
6%
4%
2%
EYE SPOT SEASON
Plant or Harvest During March
Apply Fertilizers During April
1st GROWING SEASON
Apply Fertilizers During March
2nd GROWING SEASON
O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1928
1929
1930
Crop = 24 Months
J.P.M. 7-28

particular areas. In studying the fields subject to this disease on any plantation, it is quite possible to segregate all fields into two classes, namely, those fields subject to eye spot and those fields not subject to eye spot.

The acreage subject to eye spot will be very small in most cases, as compared to the acreage harvested each year.

As soon as commercially possible, all the eye spot fields are to be brought into a two-year cropping system so that all harvesting or planting of susceptible canes in these fields will take place during March and April of every other year. The chart accompanying this article indicates that planting or harvesting be done during March of 1928, which is just at the end of the 1927-1928 eye spot season. It is also suggested that fertilizers be applied during April of 1928, which is well in advance of the growing season. The maximum cane growth is expected in July.

The object of applying fertilizers early the first season is to take full advantage of the growing period, and also to have practically all the nitrogen utilized by the cane plant by October, 1928, which is just the beginning of the 1928-1929 eye spot season. As illustrated on the chart, the peak of the eye spot season occurs during January and February, or when the smallest amount of cane growth is expected.

The severity of most plant diseases is greatest following rapid succulent growth of the plant. The plant tissues at this stage are very soft, and it is much easier for any parasitic organism to penetrate softer than harder tissue. The eye spot disease is no exception; therefore, it is very essential to slow up or retard the growth of the young cane plant during the winter months. This slowing up process may best be accomplished by avoiding heavy, late applications of nitrogenous fertilizers. Increasing the interval between irrigations also tends to retard the growth slightly.

The second season's application of fertilizer is to be applied during March, 1929, if weather conditions are favorable. Here again the cane has another full growing season, and the seriousness of eye spot on second year cane is more or less negligible when compared to that of young cane.

The crop that was started in March, 1928, will be harvested March, 1930, or 24 months later. This crop has been exposed to two eye spot seasons, but still it has been given the benefit of two full growing seasons.

With such a two-year cropping system it is possible to avoid having young cane entering the eye spot season. If such a method of handling only the very worst affected eye spot fields be adopted, the early sources of infection would be greatly minimized, thus offering greater protection to the surrounding fields.

Concentrating on the elimination of the foci of infection by the adoption of definite agricultural practices as outlined above, or planting such areas with highly resistant varieties, are the most economical control measures of the disease that we have to offer at the present writing.

The ultimate control of eye spot will be effected when a resistant variety that equals or excels H 109 in sugar production is found and can be planted on the affected areas. Many tests are now under way in order to find such a variety, but until this variety is found it will be necessary to resort to the control measures we now have.

At the Waialua Agricultural Company, Limited, approximately 300 acres of H 109 that are subject to severe eye spot attacks are now under the two-year cropping system outlined in this article.

Temperatures Favorable to Zoospore Development in Pythium Aphanidermatum

By C. W. Carpenter

In December, 1927, the observation was made that a low temperature favors the development of the zoospores of *Pythium aphanidermatum*. At a temperature of about 16° C (60.8° F.) a root preparation was maintained for several days in a continuous stage of sporangia formation and liberation of zoospores. During this period, whenever the preparation was taken from the cool chamber, zoospores were actively swimimng, and streaming from the prosporangia was evident. Since it takes approximately 20 to 40 minutes for zoospore liberation after the streaming of the contents of the prosporangium ceases, it is evident that these zoospores, noted immediately on removal of the preparation from the cool chamber, were developed therein. Previously the mode of formation of asexual swimming spores was recorded,* but at that time the factors necessary for their development were not appreciated. In general, they appeared to develop more readily in tap water than in distilled water, which appears now to have been due merely to the few degrees difference in temperature.

After the preparations, in which zoospore formation was active, were kept on the microscope at room temperature for a half hour or longer, the streaming of sporangia gradually ceased. When the preparation was again incubated in the cool chamber, the action was resumed with vigor.

This is an observation in which the life history of *Pythium* correlates with the history of the disease, in that cool weather favors the fungus. The disease was often said to be most noticeable in the winter months, i.e., the cool, wet weather of the year, when the growth appeared to be suddenly checked, followed in drier weather by the drying up and death of the plants. It would appear that with sufficient moisture in the soil and a subnormal temperature, the fungus, by aid of the zoospores, could spread very rapidly through a susceptible root system and thence to other root systems, and to great distances, through the watercourses and ditches. With ordinary soil moisture and temperature, the fungus in the vegetative stage, which reaches its most rapid development at warmer temperatures than the zoospore stage, could spread moderately, since it can grow several centimeters a day.

* Bulletin of the Experiment Station, H. S. P. A., Botanical Ser., Vol. III, Part 1, p. 61.

Recent Developments in the Use of Concentrated Fertilizers

By Guy R. Stewart

For many years, in the sugar industry of Hawaii, it has been the general practice to make the first season fertilizer applications to the cane crop with high grade concentrated fertilizers. These mixtures have been made up largely from nitrate of soda, potash nitrate, ammonium sulphate, superphosphate, bone meal, potassium chloride and potassium sulphate, and have contained only small amounts of inert material or filler. The amounts of plant nutrients supplied per hundred pounds of fertilizer have ranged from 10 to 12 per cent nitrogen, 3.5 to 9 per cent of phosphoric acid, and from 5 to 10 per cent of potash. Considered in comparison to many of the fertilizer formulas marketed upon the mainland of the United States, the mixtures used in the Islands would all be classed as highly concentrated. Their general employment has resulted in great savings, both in freight and in the cost of applying fertilizer.

Recent developments in the manufacture of unusually concentrated raw materials now make it possible to produce mixed fertilizers which will contain even higher percentages of plant nutrients than have been present in each hundred pounds of fertilizer made up from the old raw materials. The beginning of this manufacture of the newer concentrates can be traced back to the utilization of the war-time capacity for the fixation of nitrogen.* This has been one of the great after developments of the manufacture of munitions upon the continent of Europe. Previous to the World War, calcium nitrate, ammonium nitrate, sodium nitrite and sodium nitrate had been made in moderate amounts in Norway by the fixation of atmospheric nitrogen. Calcium cyanamid has been made at Niagara Falls, Canada, since 1909. The production at Niagara, however, though steadily increasing, has not been one of the larger factors in supplying the American market with fixed nitrogen compounds. In the United States, up to the present time, our principal sources of nitrogen have been Chilean nitrate of soda, and latterly, ammonium sulphate derived from by-product cake ovens.

A current review of nitrate production for the past year, made by Dr. L. Bueb, of the German Nitrate Syndicate (2), placed the production of all forms of nitrogen at 1,650,000 metric tons. Each metric ton is equivalent to 1.102 short tons of 2,000 lbs. each. Of the total nitrogen stated above approximately 50 per cent was Chilean nitrate and 40 per cent was fixed nitrogen manufactured in Germany. The other 10 per cent of fixed nitrogen covers the production in France, Italy, Norway and North America. When we consider that prior to the World War the production of Chilean nitrate was estimated to cover more than 95 per cent of the world's supply of combined nitrogen, it is easy to see the tremendous increase in the fixed nitrogen industry which has come about as a by-product of the war time activity in munitions.

Previous to 1914 the fixed nitrogen products most commonly manufactured were calcium cyanamid, with a nitrogen content ranging from 16 to 18.5 per cent, and calcium nitrate, containing approximately 13 per cent of nitrogen. Immediately after the World War, ammonium nitrate was imported from Europe to the United States with a nitrogen content of 34.5 to 35 per cent. More recently a new series of synthetic nitrogen products have been manufactured in Germany. Prominent among these new materials are leuna saltpeter which consists essentially of a mixture of equal parts of ammonium sulphate and ammonium nitrate crystallized together to form a homogeneous salt. Calcium nitrate is also being made with a higher content of nitrogen averaging about 15.5 per cent of nitrogen. It is also claimed that this nitrate of lime is notably less hygroscopic than the older forms of lime nitrate. Trial shipments received here in Hawaii have, however, taken up appreciable quantities of moisture if exposed to the air for any length of time.

Urea is now being made in appreciable amounts from synthetic nitrogen salts. This material is highly concentrated, as it contains 46 per cent nitrogen. Cal-urea is a mixture of equal parts of calcium nitrate and urea. Trial shipments of cal-urea received here have contained 34.3 per cent total nitrogen, of which 6.5 per cent was nitrate nitrogen, 0.5 per cent ammonia nitrogen, and 27.3 per cent was amid nitrogen. There was also 12.77 per cent of lime furnished by the lime nitrate contained in the material.

It is also possible to combine these various synthetic nitrogen salts with phosphoric acid, as in "ammo-phos," and then add a potash salt to the mixture. A series of such mixtures is being manufactured in Germany. One trial shipment has been received in the Hawaiian Islands consisting of "Nitrophoska 1 G." This material was a granular product which did not absorb moisture to any extent when exposed to the air. It contained 16.5 per cent total nitrogen, of which 11.3 per cent was ammonia nitrogen and 5.29 per cent was nitric nitrogen. There was also 16.5 per cent of phosphoric acid and 20 per cent of potash in the mixture. Several other formulas of "Nitrophoska" are being sold in Europe and the Eastern United States.

In considering the value of any of these newer forms of fertilizers there are several points which enter into the solution of such a problem. First among these may be mentioned the effect of the fertilizer or its decomposition products upon the plant and its secondary action upon the soil. There is, then, the question of the compatibility of the material with other possible fertilizer ingredients, both in regard to chemical interaction, which may involve the loss of volatile nitrogen, and the formation of toxic products. There is finally the matter of the value of the small amounts of impurities present in the materials which have been formerly used. A study of the nature and amount of these impurities in the older fertilizer ingredients was reported by Hansson, in the July *Record* (9). A similar investigation upon the newer forms of material now available is being carried out by Van Brocklin and will be presented in the next issue of the *Planters' Record*.

It may be of interest to discuss some of the more important investigations which have been carried out with the various synthetic fertilizers. The major

portion of these studies has been conducted in the Eastern United States or in Europe, but they give a good indication of the value of the materials used upon average agricultural crops, and of the secondary effect of the fertilizer upon the soil.

Calcium Cyanamid

A comprehensive series of experiments have been carried on with calcium cyanamid and other synthetic forms of nitrogen at the New Jersey Station(13). It was concluded that the synthetic nitrogen, including calcium cyanamid, gave as good average returns as the sodium nitrate and ammonium sulphate.

Allison and his co-workers(1) in Alabama, have reported an extensive series of field experiments with atmospheric nitrogen compounds. They concluded:

> Calcium cyanamid usually was not as satisfactory as the other sources of nitrogen, chiefly because so many factors influence the rate and manner in which the material is decomposed either in fertilizer mixtures or in the soil. When mixed with acid phosphate in large proportions the results were poor, probably owing to the transformation of a portion of the cyanamid nitrogen to dicyanodiamid, a compound which is not only unavailable but toxic for some crops and for the nitrifying bacteria. Where applied separately with acid phosphate the results were good, even with 1000 pounds of an 8-8-4 fertilizer. Calcined phosphate and basic slag appear to be entirely satisfactory as to compatibility as sources of phosphorus for use with cyanamid.
>
> The behavior of cyanamid in the soil depends upon a number of factors, such as time and method of application, and the type, composition, temperature, and moisture content of the soil. Application should be made at the time of seeding, or, preferably, earlier. It is therefore believed that thorough mixing of the cyanamid with the soil is preferable to drilling in the row. Even under the best conditions cyanamid nitrogen is converted to nitrates rather slowly, and for this reason is usually slow to act. The soil conditions which are known to hasten nitrification are, in general, the ones which favor an efficient utilization of cyanamid.

It has been noted in the fertilizer trade journals that when calcium cyanamid is used in mixed fertilizers in moderate quantities it serves as a conditioner, keeping the mixture loose and friable. Under the best conditions a considerable part of the nitrogen of calcium cyanamid is converted into urea, the chief effective nitrogenous constituent of liquid manure. The nitrogen of calcium cyanamid is classed as "organic" by the Association of Official Agricultural Chemists.

Ammonium Phosphate or "Ammo-phos"

Owing to the difficulties previously mentioned, which may at times attend the use of calcium cyanamid, a considerable portion of the nitrogen combined in this form at Niagara Falls, is later converted over into two forms of ammonium phosphate. One formula of ammonium phosphate contains 16.45 per cent nitrogen and 20 per cent phosphoric acid. The second furnishes 10.7 per cent nitrogen and 48 per cent phosphoric acid.

A number of experiments with ammonium phosphate have been made both in Europe and in the United States. Allison and his co-workers(1) concluded that ammonium phosphate and ammoniated superphosphate gave an excellent early

growth with both cotton and corn. Both crops when fertilized with these materials were as large or larger than those obtained with any treatments during the first six weeks of growth. The nitrogen of the two materials was as available as that in ammonium sulphate and showed no bad effects except in case of extreme drought, where large applications of all soluble salts injured the plants. Both substances were considered to be good nitrogen carriers.

The growth during the latter half of the season in Allison's experiments, continued to be good, but owing to the abnormally large quantities of phosphate supplied to both the checks and the ammonium phosphate treated plots, the differences became less pronounced as the season advanced. The soil used in these experiments was one which tended to give a notable response to phosphates, so the final result largely obliterated the effect of the added nitrogen derived from the ammonium phosphate.

Coe(5) carried out an extensive investigation at the New Jersey Station in which he used "ammo-phos" as one of the sources of nitrogen and phosphoric acid. The crops used included potatoes, corn, cotton, buckweat, and soy beans. He made numerous trials to try to determine the best method of applying his fertilizer mixtures so as to have the nutrients in the zone of early root development and still avoid temporary injury to the plant. His general conclusions were that the ammonia of the "ammo-phos" furnished a supply of nitrogen which was readily available for the plant's use. The phosphate content appeared to be equally as valuable as that derived from other phosphate sources.

Calcium Nitrate

Shipments of Norwegian nitrate of lime were made for a number of years to Hawaii. Some plantations are still continuing to use lime nitrate, but considerable difficulty was experienced in handling this fertilizer during periods of wet weather owing to the rapidity with which it absorbed moisture. The lime content of this nitrate was also found to be extremely irritating to small cuts upon the laborers' hands.

Experiments carried out at Waipio substation, as well as upon several of the plantations, showed that nitrate of lime was equal to nitrate of soda as a fertilizer for cane. This agrees with the results obtained in numerous experiments which have been conducted in Europe with a variety of crops.

The new lime nitrate now imported from Germany is a white crystalline product. Approximately 4 per cent of ammonium nitrate has been added to this new material to aid in crystallization and to increase the nitrogen content. We have previously referred to the fact that this new nitrate of lime readily takes up moisture if exposed to the air.

Ammonium Nitrate and Leuna Saltpeter

During the period that ammonium nitrate was being imported into Hawaii, the writer gave a resumé in the *Planters' Record*(14) of experiments in which it had been used. These experiments indicated that ammonium nitrate was a valuable fertilizer which gave results comparable to those obtained with either nitrate of

soda or ammonium sulphate. This conclusion was confirmed by the results of field experiments at Waipio substation, where the same yield of cane was obtained with equal amounts of nitrogen derived from ammonium nitrate and nitrate of soda.

Ammonium nitrate has given considerable difficulty in humid climates through its tendency to absorb moisture and later solidify in a solid cake. In order to overcome this trouble, and also to avoid the import duty levied on ammonium nitrate, this salt has been combined with an equal amount of ammonium sulphate while the two salts were still in solution. The product after crystallization is a combination of the two compounds, and is only moderately hygroscopic. The trade name of this combined salt is "Leuna Saltpeter." A few trial shipments have been received in Hawaii. This fertilizer has a nitrogen content of 26 per cent, of which 19 per cent is ammonia nitrogen and 7 per cent nitrate nitrogen.

Kuyper(11) has carried out several series of field trials with leuna saltpeter upon sugar cane in Java. The nitrogen derived from this source was compared with the nitrogen of ammonium sulphate. Equally good yields were obtained with both nitrogen salts. Graftiau and Hardy(8) used leuna saltpeter upon field crops in France. The return was as good as with nitrate of soda and sulphate of ammonia.

Urea and Cal-Urea

The most concentrated nitrogenous fertilizer so far developed is urea, which, as we have mentioned previously, contains 46 per cent of nitrogen. Although it is a comparatively new material to be produced on a large commercial scale, a sufficient amount has been manufactured in the past so that a large number of experiments have been conducted with it in various European countries and in Java.

In general the crop yields obtained with urea have been favorable to this material, though there were some conflicting reports as to its value. Von Knieriem(10) in Germany, found that urea gave better results with stock beets and potatoes than he obtained with leuna saltpeter or ammonium sulphate. Chevalier(4), in France, carried out a series of pot experiments with spring wheat in which urea gave yields equal to those obtained with nitrate of soda.

Truffant and Bezssonov(15) experimented for four years with urea and a series of mixtures of nitrogenous salts consisting of ammonium sulphate, sodium nitrate, ammonium nitrate and cyanamid. The crop used consisted of mustard, barley, beets and potatoes. The best yields were obtained when urea was combined with one or more of the other forms of nitrogen. The results for these partial urea mixtures excelled those obtained with urea alone.

Kuyper(12) and van Harreveld-Lako(16) both carried out field trials and laboratory tests with urea as a fertilizer for sugar cane in Java. They both reported that urea was too hygroscopic for Javanese conditions. Kuyper carried out a series of leaching trials with urea in soil columns. He concluded that the probability of loss by leaching was too great to justify the extensive use of this material in Java.

Brioux(3) studied the changes in soil reaction of several French soils when additions of urea, ammonium sulphate and nitrate of soda were used. Up to two days, urea caused an increase in alkalinity, due to the formation of ammonium carbonate. After this time nitrification proceeded rapidly and the soil was finally more acid than was originally the case. With ammonium sulphate on these same soils there was, in a few cases, at first a slight increase in alkalinity. This was followed in all soils by a steady change of reaction towards the acid side. With nitrate of soda there was first an increase of alkalinity and then a decrease, though the final reaction of the soil was slightly more alkaline than it had been previously.

Couterrier and Perraud(6), likewise working in France, found that urea was converted over to ammonium compounds and nitrates with great rapidity in average soils. Craig(7) made this same observation in his experiments in Mauritius, and reported that urea compared favorably with nitrate of soda and ammonium sulphate in availability. He noted, however, that urea was extremely hygroscopic under Mauritius conditions and could not be mixed with soluble superphosphates.

No extended investigations have been reported with "cal-urea," but there is every reason to believe that the results obtained with it upon crop growth will be similar to those reported for urea alone.

Nitrophoska

These materials, as previously mentioned, contain high percentages of nitrogen, phosphoric acid and potash. The formula No. 1 G, a shipment of which has been received here in Hawaii, is not appreciably hygroscopic. In the Eastern United States, nitrophoska No. 3 has been offered for sale. This material contains 15.6 per cent nitrogen, 32 per cent phosphoric acid and 16 per cent potash. It is probable that these materials will be used as the basis of high analysis concentrated mixed fertilizer by the addition of nitrogen, phosphates or potash salts to suit the needs of special districts.

Double and Treble Superphosphate

These materials are an excellent source of concentrated available phosphates. Irrespective of whether they are called double or treble superphosphates, the amount of phosphate present ranges from 45 to 52 per cent of phosphoric acid. These high grade superphosphates promise to be a great convenience to the fertilizer manufacturer in making up formulas with a large content of available phosphate.

In conclusion, it may be stated that the survey of the literature which the foregoing discussion summarizes briefly, indicates that the new concentrated sources of nitrogen and phosphoric acid give every promise of being fully as valuable for agricultural crops as the materials previously employed. In addition, there is a notable saving possible in freight and handling charges in applying less bulky fertilizers.

BIBLIOGRAPHY

(1) Allison, F. E., Braham, J. M., and McMurtrey, J. E. Field experiments with atmospheric nitrogen fertilizers. U. S. Dept. Agr. Bull. 1180, pp. 1-43, Jan., 1924.
(2) Anonymous. Status of German nitrate industry. Wall Street Journal, August 9, 1928, p. 8.
(3) Brioux, Ch. Influence de l'uree employee comme engrais sur la reaction du sol. Comptes Rendus 179, 1924, pp. 915-917.
(4) Chevalier, Gaston. Experiments on the utilization of synthetic urea as a nitrogenous fertilizer. Prog. Agr. vit. 80, 257-60 (1923). CA Vol. 14, 1924, p. 3903.
(5) Coe, D. G. "Ammo-Phos", its effects upon seed germination and plant growth. New Jersey Agric. Expt. Sta. Bull. 375, pp. 1-102, 1923.
(6) Couterrier, F., et Perraud, S. Sur quelques proprietes de l'uree vis-a-vis des sols. Comptes Rendus 1880, pp. 1433-1436 (1925).
(7) Craig, N. The use of urea as a nitrogenous fertilizer. Rev. Agr. Maurice 4, pp. 322-323 (1927).
(8) Graftiau, J., and Hardy, P. The fertilizing value of mixed ammonium sulfate-nitrate. Bull. Soc. Chim. Belg. 33, pp. 465-7 (1924) CA 19, 1925, p. 147.
(9) Hansson, Fred. Some unusual constituents present in common fertilizers. Planters' Record, Vol. 32, No. 3, pp. 342-346.
(10) Von Knieriem, W. Fertilizer experiments with new nitrogen fertilizers. Mitt. deut. Land. Ges. 37, pp. 654-655 (1922), CA Vol. 17, 1923, p. 1296.
(11) Kuyper, J. Ammonium sulfate-nitrate and urea as nitrogenous fertilizers. Arch. Suikerind. 31, pp. 21-25 (1923).
(12) Kuyper, J. Comparison of urea with ammonium sulfate as nitrogenous fertilizer. Arch. Suikerind. 32, 3 Deel, 1924, pp. 509-532.
(13) Lipman, J. G., and McLean, H. C. The agricultural value of some of the newer nitrogenous fertilizers. Journ. Ind. Eng. Chem. Vol. 17, No. 2, February, 1925, pp. 190-192.
(14) Stewart, G. R. Ammonium nitrate, a new high grade fertilizer. Planters' Record, Vol. 24, No. 2, pp. 91-94.
(15) Truffant, G., and Bezssonov, N. Sur la forme de l'azote la plus favorable aux plantes superieures. Comptes Rendus 178, pp. 723-725 (1924).
(16) van Harreveld-Lako, C. H. Absorption and leaching of nitrogen in fertilization with urea and ammonium chloride. Arch. Suikerind. 32, 3 Deel, pp. 261-267 (1924).

Notes on the Rice-Borer, Chilo Simplex

By R. H. Van Zwaluwenburg, E. W. Rust and J. S. Rosa

The recent introduction into Oahu of the rice-borer, a pyralid moth known as *Chilo simplex* (Butl.), confronts the Hawaiian rice industry with a pest of major importance, which, unless brought under control, threatens to seriously cripple rice growing in this Territory. As far as is known this insect is not a pest of sugar cane.

As soon as the importance of the rice-borer was realized, the Territorial Board of Agriculture and Forestry and the Experiment Station of the Hawaiian Sugar Planters' Association undertook as a cooperative project the introduction of rice-borer enemies from the Orient. D. T. Fullaway, of the Board of Agriculture and Forestry, and F. C. Hadden, of this Station, left for Japan in March to obtain parasites, which have been handled in Honolulu by the writers.

Origin and Introduction

The presence of a moth larva new to these Islands, working within the stems of rice, was first called to the attention of Mr. Fullaway on March 1 of this year, by K. A. Ching, of the Pacific Guano and Fertilizer Company. The rice growers at Honouliuli, from whom the original complaint came, stated that they had first noticed the work of the insect in the fall of 1927. A rice-straw buyer in close touch with the industry, claims to have noted borer work in straw for the past five years.

Oahu is the only island of this group at present known to be infested by the rice-borer.* All rice lands of the island show greater or less infestation at the time of writing. A territorial quarantine now in effect against the movement of rice-straw in any form to the outlying islands will, it is hoped, keep the rest of the group free from the pest.

It is reasonably certain that the rice-borer is an immigrant from Japan, where it is a recognized pest. That it gained entrance to the Territory in rice-straw used as packing for merchandise also seems certain, for since its discovery in the fields here it has on several occasions been intercepted by Territorial quarantine officials in such material from Japan, and rice-straw has been used as packing for many years.

Chilo simplex was originally described from Formosa, and is known in Japan as the "two-brooded rice-borer" to distinguish it from an even more serious pest known as the "three-brooded rice-borer" (*Schoenobius incertellus* [Walker]). It is not certain that *Chilo simplex* occurs in India. The moth called *simplex* in India is a pest of rice and of sugar cane, but on comparison of larval descriptions it seems probable that it is not the *simplex* of Formosa, Japan and Oahu. On the other hand, *Chilo oryzae* Fletcher, of India, reported on rice only, corresponds closely with our *simplex*. The numerous members of this genus of moths are in need of careful study, and only a competent examination of type-material can determine the relation of the Indian species to our own.

Nature and Severity of Damage

The typical symptom of *Chilo* attack in rice is the killing of the central leaf. This is caused by the larva feeding within the stem and killing the tender inner leaf-tissues. Badly infested rice shows a high percentage of dead shoots and leaves; is easily flattened by wind and rain, and often, even though the head forms, fails to set grain. The loss has become so severe in some sections that at least one small grower has abandoned the planting of rice. A Japanese grower at Heeia states that a field (area not specified) which has hitherto always produced between 30 and 40 bags, will this crop yield not more than 5 or 6 bags. This grower last year noticed the rice-borer in small numbers for the first time. At Honouliuli several small areas were so badly damaged that no attempt was made to harvest the July crop. It is stated (with what accuracy is not certain) that the Hawaiian

* Since the above was written, this insect has been found widespread on the island of Kauai.

variety of rice suffers more than the Japanese variety, which matures in about a month's less time than the former.

The eggs of the rice-borer are disc-shaped, creamy-white when first laid, and are deposited in irregular clusters, either on the leaf-blade or tucked down between the leaf-sheath and the main stem. The eggs, which are overlapped like shingles, often number over 100 in a single cluster. They hatch in from six to seven days. The young larvae make their way down the leaf and enter the stem, where they commence their feeding. When full-grown the larvae are about an inch in length. The pupal stage of about ten days is passed within the stem.

Large numbers of adult *Chilo* moths are caught by light-traps, and trapping gives promise of being a practical means of reducing the rice-borer population.

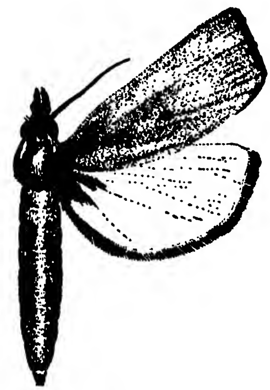


Fig. 1

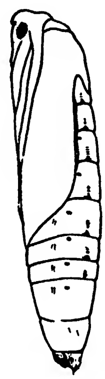


Fig. 2

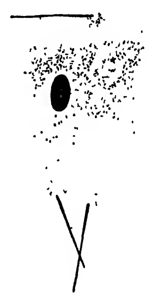


Fig. 4

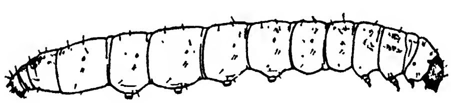


Fig. 3

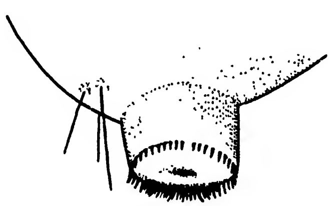


Fig. 5

Various stages of *Chilo simplex* and anatomical details of larval structure. The enlargements are not uniform.

Fig. 1. Adult male moth (wings of left side removed).
Fig. 2. Pupa.
Fig. 3. Full-grown larva.
Fig. 4. Larval spiracle and setae.
Fig. 5. Abdominal proleg of larva.

Host Plants

The preferred host of the rice-borer is undoubtedly rice. Occasionally barnyard grass (*Echinochloa crusgalli* var. *cruspavonis* [H. B. K.]) and rice grass (*E. stagnina* [Retz.] Beauv.) standing amid growing rice are also attacked, but as a rule plants other than rice usually show little infestation as long as there is standing rice in the vicinity. Once the rice has been cut, however, especially if heavily infested (individual rice stems have often been found to contain upward of ten mature larvae), the rice-borer takes to a number of other plants. It is possible that the borer larva migrates to such hosts from dead stubble or straw, for neither eggs nor young larvae have been found in association with anything but rice.

The most important host of the rice-borer at Honouliuli, in the absence of rice, was the common barnyard grass (*E. crusgalli* var. *cruspavonis*). In July this grass was severely infested, hardly a stem escaping attack, and many of the stools being killed outright. At the same time borers were found to be present in a number of the other grasses, among them: goose grass (*Eleusine indica* [L]); foxtail grass (*Chaetochloa verticillata* [L]); and rarely, Panicum grass (*Panicum barbinode* Trin.). Hilo grass (*Paspalum conjugatum* Berg.) has never been found to contain rice-borer larvae, though a few short burrows have been found in it, suggesting that this grass is either too hard for the borer or distasteful to it. Larvae were found to be fairly common in stems of a composite weed (*Eclipta alba* Hassk.) just after the rice was harvested. Recently Q. C. Chock, of the Board of Agriculture and Forestry, found extensive tunnels in the stems of *Phaseolus lathyroides* L. made by a lepidopterous larva believed to be the rice-borer.

Not a Pest of Sugar Cane

No trace of rice-borer has yet been found in sugar cane on Oahu, even when in close proximity to either standing or harvested fields of heavily infested rice. Mr. Hadden writes that in Formosa sugar cane is rarely, if ever, attacked by *Chilo simplex,* and suggests the possibility that previous records of such attack may be attributed to the presence in that country of a closely related and scarcely distinguishable borer. It is well known that certain species of *Chilo* in other countries (notably *Chilo loftini* Dyar in Mexico) seriously attack sugar cane in addition to rice and other grasses. It is conceivable that the rice-borer present here may ultimately transfer its attention to sugar cane, for in the laboratory partially grown larvae placed on seedling varieties grown from cuttings caused the death of the young shoots. There is, however, no cause for immediate alarm as concerns the cane industry; in fact, the situation becomes more and more encouraging as the negative field evidence accumulates.

Local Enemies

Several enemies already established here have been noted preying on the rice-borer:

1. *Trichogramma minutum* Riley, an egg-parasite of cosmopolitan distribution, has been reared from *Chilo* eggs collected at Honouliuli.

2. An ichneumonid wasp, *Nesopimpla naranyae* Ashm. occurred in large numbers in rice fields in June and July, and was bred from infested straw. Its parasitism of *Chilo* is not proven, but is probable.

3. *Cremastus hymeniae* Vier., an ichneumonid parasitizing many kinds of lepidopterous larvae, has on two occasions been reared from rice-straw in which its cocoon was found beside the remains of a dead *Chilo* larva. This species has also been noted in rice fields on various occasions.

4. *Polistes hebraeus* (Fab.), a common yellow wasp, was present in numbers in lately cut fields at Honouliuli in June. It was repeatedly observed cutting rice-borer larvae and adults into small pieces, which it rolled into pellets and carried off, presumably to store its nest.

5. Stray larvae of the rice-borer are frequently attacked by the ubiquitous lowland ant, *Phidole megacephala* (Fab.).

6. The mynah bird (*Acridotheres tristis*) undoubtedly accounts for large numbers of *Chilo* larvae and moths, which it picks up in the open fields after the cutting.

Foreign Enemies

Mr. Fullaway and Mr. Hadden had, up to August, forwarded from Japan ten different lots of insects attacking *Chilo simplex*. These included:

Parasites of the egg:
- *Phanurus beneficiens* (Zehnt.)
- *Trichogramma japonicum* Ashm.

Parasites of the larva:
- Undetermined ichneumonid.
- *Cremastidea chinensis* Vier.
- *Apanteles* sp.
- *Amyosoma chilonis* Vier.

Predaceous enemies:
- Larvae of an undetermined species of carabid beetle.

The egg-parasites were all reared through a first generation before release in the field. By the middle of August over 33,000 *Trichogramma japonicum* and over 24,000 *Phanurus* had been released in Oahu rice fields. *T. japonicum* has several times been reared from *Chilo* eggs collected in the field, so there is a good likelihood of its establishment here. It is closely related to *T. minutum*, and, like it, is said to attack a wide range of lepidopterous eggs. *Phanurus* is more restricted in its habits, attacking the eggs of only *Chilo* and *Schoenobius*, as far as is known. This last egg-parasite is a native of Java, whence it was introduced into Formosa and later into Japan.

The only others of the above list to be released here were small colonies of *Amyosoma* and of *Apanteles* spp. (including one species parasitic on the cabbage butterfly).

Variation of Soil Depth Within Limited Areas

By J. P. Martin

In an attempt to explain the low yields obtained from Field Mill 5 during the 1928 crop of the Waialua Agricultural Company, Ltd., H. P. Agee, upon visiting the field May, 1928, with Messrs. Verret and Stewart, of this Station, suggested that a few soil borings be made in the field in order to ascertain the soil depth and other possible factors that might have a direct bearing on the low yields.

During the latter part of May, 1928, the writer made a few soil borings, and since there was such a wide variation in depth within a short radius, it was decided to make a series of borings along the level ditches of the field. A total of 32 borings were made and a graphic presentation of the results is best made by the use of small wooden pegs as shown in Fig. 1. In preparing the model for photographing the length of each peg in mm. represented the depth of the soil in inches at that particular location. In Fig. 2 a diagram illustrates the location and depth of soil at each boring.

At the bottom of each boring a hard, thick, coral layer was found which was impervious to water. Field Mill 5 is in a low lying area which heretofore was occupied by the ocean. A possible explanation of the great variation in soil depth may be visualized by observing the irregularities of the ocean floor from a glass-bottom boat, and imagining such a surface covered with soil.

The average depth of soil in Field Mill 5 was comparatively shallow. It was finally agreed that in order to secure greater yields it would be necessary to continue irrigations up to two months previous to harvesting, especially if harvested during the summer months; the application of slightly more fertilizer than the usual practice was also thought to be advisable.

As an outcome of the above investigations the following fertilizer experiment was put in Field Mill 3, which is very similar to Field Mill 5, by R. E. Doty, of the Experiment Station:

	1st Season Nitrogen	2nd Season Nitrogen	Total Nitrogen
6-A Plots......................	50	150	200
6-B "	150	50	200
6-C "	100	100	200

All nitrogen was from nitrate of soda.

Here again the writer made a series of soil borings in each watercourse of the area which was selected for the experiment. Approximately three soil borings were made in each watercourse. The results of the findings are best presented by the graphic presentation as shown in Fig. 3, which was prepared in a like manner to that in Fig. 1. In Fig. 4, a diagram gives the plan of the experiment, the location and depth of each boring made.

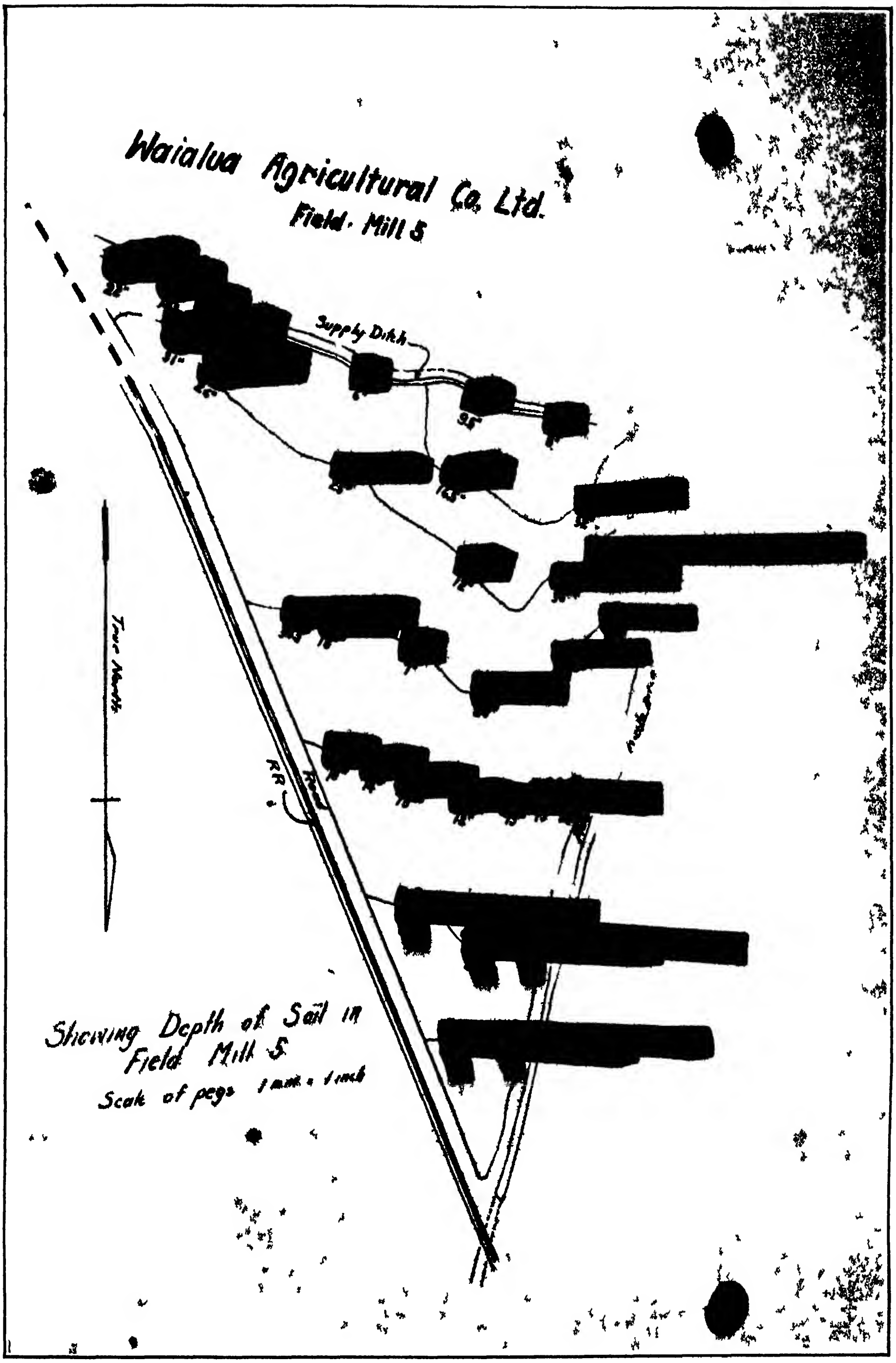

Waialua Agricultural Co. Ltd.
Field. Mill 5
Supply Ditch
True North
RR
Road
Showing Depth of Soil in Field Mill 5
Scale of pegs 1 mm = 1 inch

Fig 1

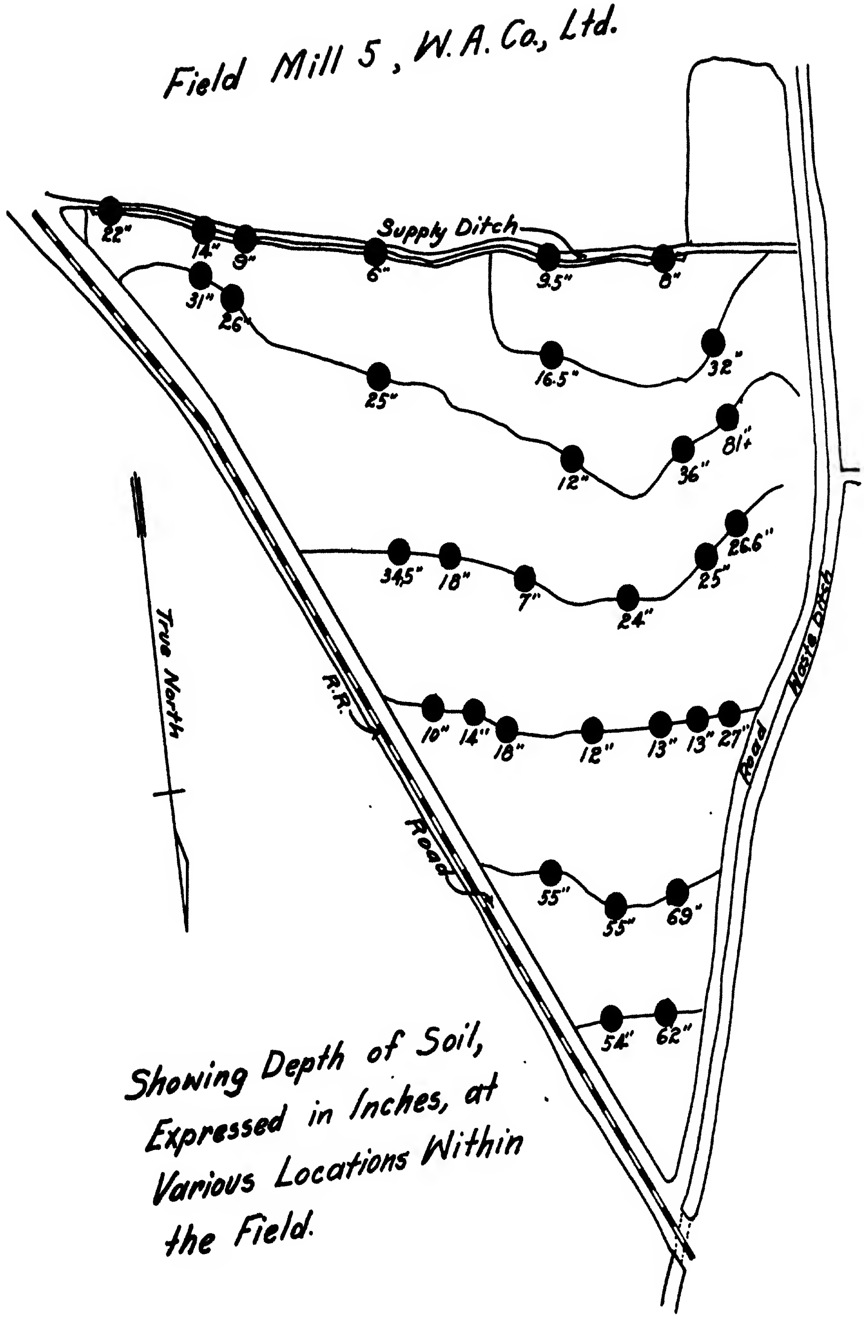

Field Mill 5, W.A. Co., Ltd.
Supply Ditch
22"
14"
9"
6"
9.5"
8"
31"
26"
25"
16.5"
32"
12"
36"
81+
34.5"
18"
7"
24"
25"
26.6"
10"
14"
18"
12"
13"
13"
27"
55"
55"
69"
54"
62"
True North
R.R.
Road
Road
Waste Ditch
Showing Depth of Soil, Expressed in Inches, at Various Locations Within the Field.

Fig. 2

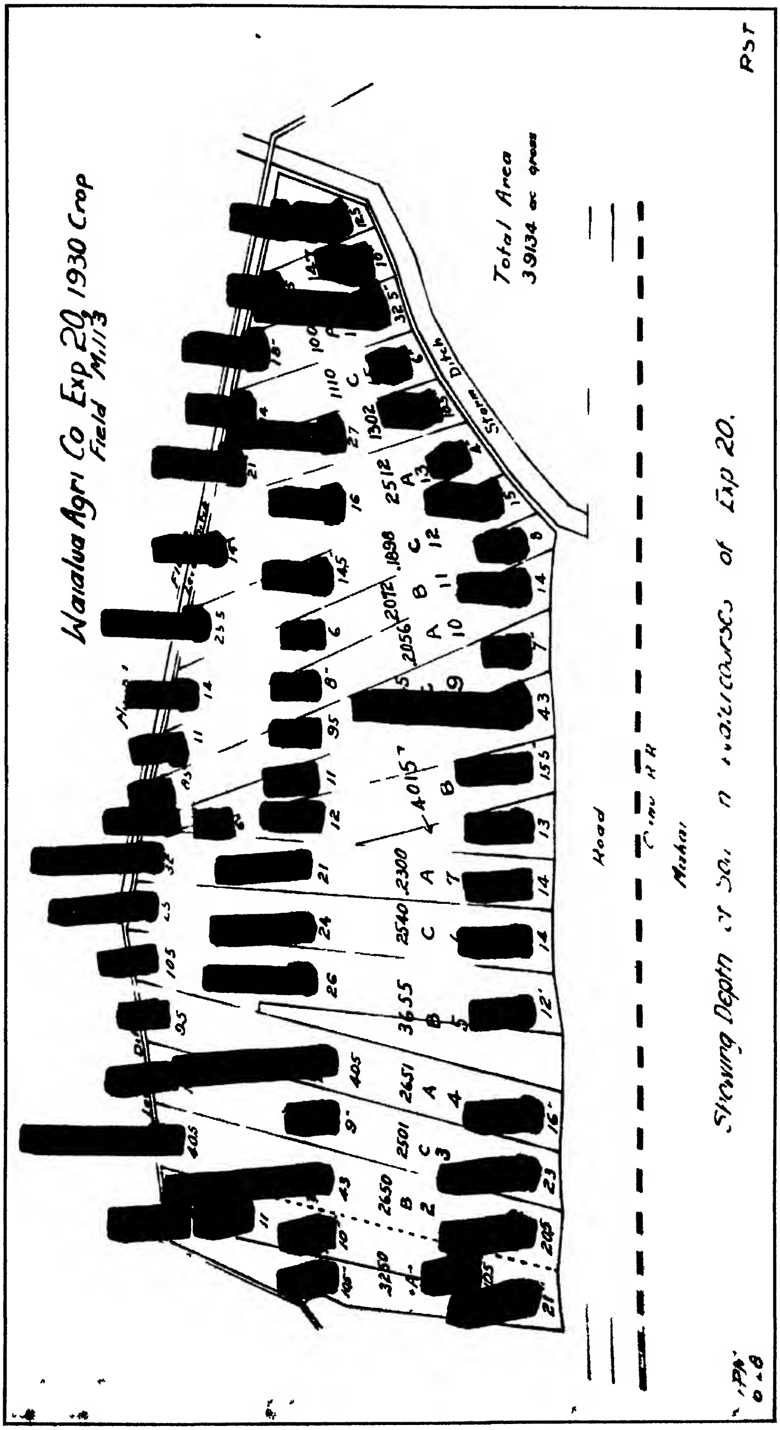
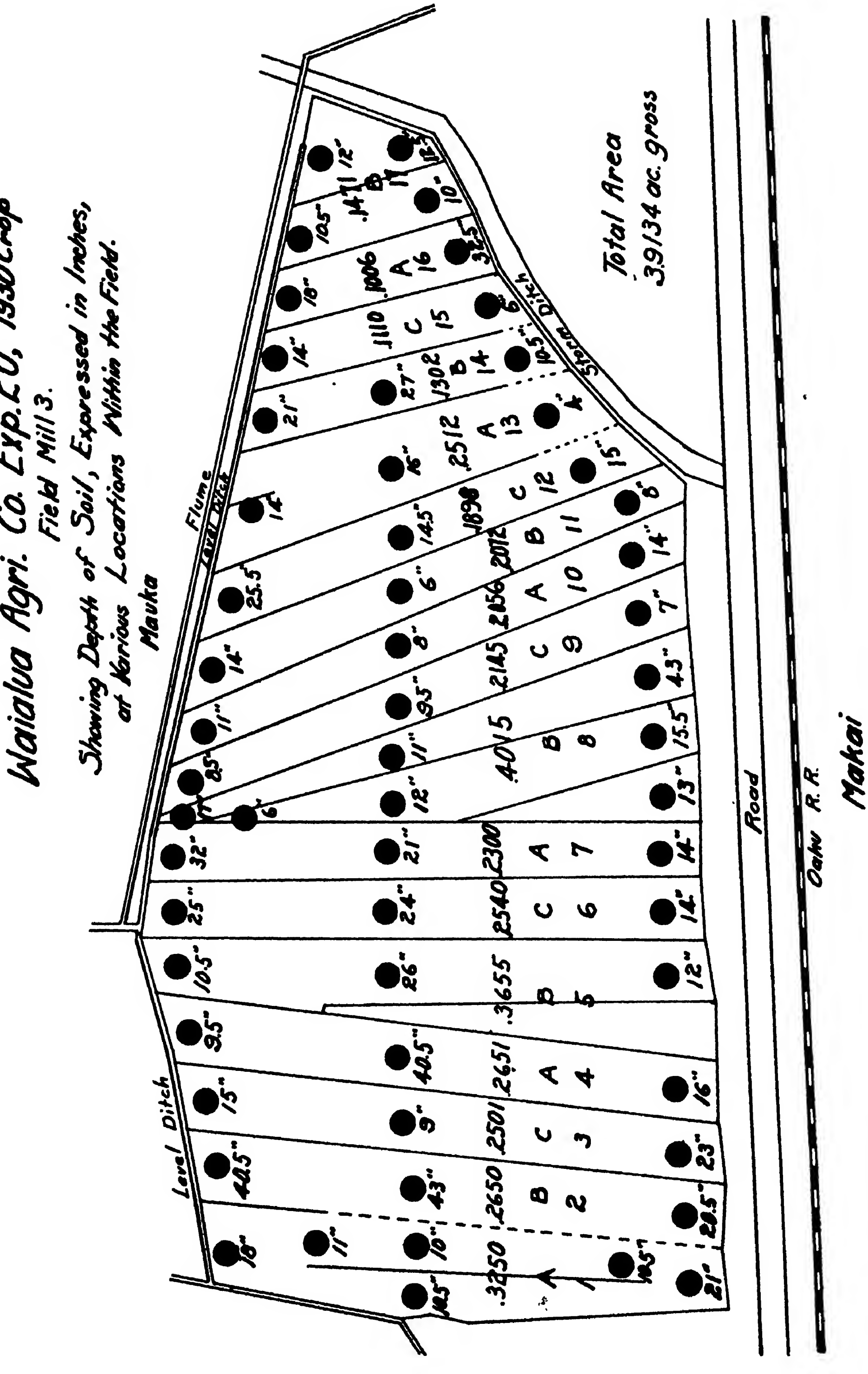

Waialua Agri Co Exp 20 1930 Crop
Field M.113
Total Area
Storm Ditch
Road
of Exp 20.

Fig. 3



Waialua Agri. Co. Exp. 20, 1930 Crop
Field Mill 3.
Showing Depth of Soil, Expressed in Inches,
at Various Locations Within the Field.
Mauka
Flume
Level Ditch
Level Ditch
Storm Ditch
Total Area
39.134 ac. gross
Road
Oahu R. R.
Makai

Fig. 4

A hard coral layer was encountered at the bottom of each boring, as was the case in Field Mill 5. In this experiment the depth of soil varied from 4 to 43 inches. The average depth of soil was quite shallow. In order to secure the maximum yields from such fields it seems very essential to keep a good supply of moisture in the soil, even quite close to the harvesting period, so as to prevent the soil from drying out and the cane from dying in the extremely shallow areas.

Often the great variation in results of an experiment might be to a large extent understood if the soil depth was determined. The object of this paper is to show the variation of depth of soil it is possible to have in a limited area, and also to point out that a series of soil borings might aid in explaining the irregular or inconsistent results that often occur in variety or fertilizer experiments.

The Koloa System of Irrigation

By H. R. Shaw

The Koloa Sugar Company is now changing the layout in all fields formerly irrigated by means of the single line or "Hawaiian furrow" system to a method of irrigation which has been developed on the plantation. This new system of irrigation promises to be most effective in applying an even distribution with the greatest economy of labor and water. The Koloa system is not a radical departure from the present practice, but is the utilization of the best features of several standard methods used for years in the islands, supplemented by an original feature which more than doubles the effectiveness of the Hawaiian furrow system.

The Koloa system, on an average of ten irrigations, has more than tripled the acreage covered daily by each irrigator, with half the application of water used by the common Hawaiian furrow system of irrigation.

Layout: The field is prepared for the so-called two-way system, which is already well known on most plantations. The watercourses are 30 feet wide, and are prepared so that the water is diverted simultaneously from one watercourse to the furrows lying directly opposite each other. A dam is placed down the center of every two watercourses, thus making each line 30 feet long.

An important feature in the layout of the field is that the spillway from watercourse to line is about six inches higher than the bottom of the watercourse. Hence, when the line is filled with water there is no backflow and wastage in the watercourse.

The original feature, and the one which gives the Koloa system its great economic value, is in the use of a portable pani. The pani framework is constructed from three pieces of ½"x1"x2', formed as a triangle. At the apex of the triangle is a board ½"x8"x8", with rounded corners, which is placed as a base support. The framework is covered with burlap bagging, such as old fertilizer or

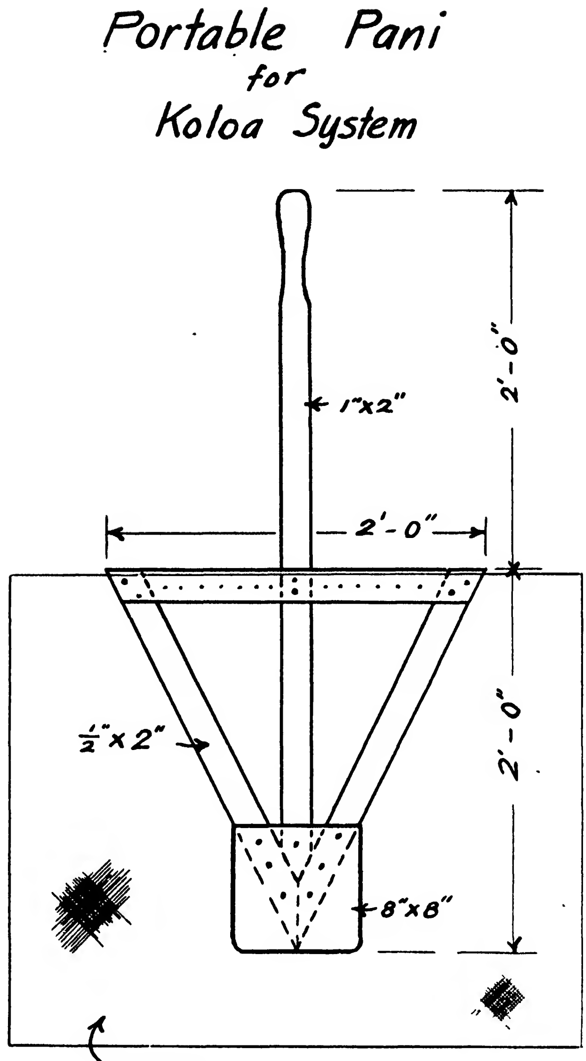


Fig. 1

sugar bags. The bagging is tacked across the broadest side of the triangle, and falls loosely across the framework. A handle of 3″ board, tapered at the top, is nailed to the base support and across the framework. These specifications are approximate only and may vary to suit local conditions.

The pani is placed in the watercourse just below the spillway to the first line. The base support is put in the bottom of the watercourse, and the sides of the bag extended over the spillway. The system can handle a large stream of water, which is diverted over the spillway and into the furrow. The line is filled quickly, and the water cannot drain back into the watercourse because of the high spillway.

When the first two lines are filled the irrigator pulls his pani down the watercourse to the next spillway, and the process is continued for the next unit.

Results: Results of ten irrigations in mature cane show that the system is effective under field conditions; and promises a sound, efficient method of handling one of our major irrigation problems.

The following results are in H 109 cane, eight to thirteen months old, on level land. The field was not especially prepared for the Koloa system, but is a ratoon field with the layout of the watercourses changed to fit the new method.

H109, THIRD RATOONS. LEVEL LAND—12.04 ACRES. FIELD 7B. STARTED MAY, 1927

	Total Water		Ac. In. per Ac.		Gals. per M.D.		Ac. per M.D.	
	One Line	Koloa	One Line	Koloa	One Line	Koloa	One Line	Koloa
Rd. 9.....	1,520,095	953,114	3.301	2.915	124,089	317,705	1.384	4.01
Rd. 10.....	2,013,759	982,441	4.373	3.005	141,316	327,480	1.190	4.013
Rd. 11.....	2,155,504	1,015,026	4.680	3.105	151,263	338,342	1.190	4.013
Rd. 12.....	2,202,753	1,063,903	4.783	3.254	149,339	303,972	1.150	3.440
Rd. 13.....	2,724,114	1,129,074	5.915	3.453	209,547	396,166	1.305	4.225
Rd. 14. ...	2,996,200	1,106,264	6.506	3.384	190,235	368,755	1.077	4.013
Rd. 15.....	3,066,258	1,282,224	6.658	3.922	278,751	466,263	1.542	4.378
Rd. 16.....	3,234,071	1,524,983	7.02	4.66	340,428	406,662	1.785	3.211
Rd. 17.....	4,775,795	1,623,738	10.37	4.96	353,762	463,639	1.256	3.440
Rd. 18.....	4,047,069	2,017,018	8.79	6.17	311,313	403,404	1.305	2.408

The following data are available on the first five irrigations in a plant field especially prepared for the Koloa system. Mr. Moir, manager, remarks: "Field 40 has not yet reached the stage where full advantage of the new system may be taken. Rains made more frequent rounds unnecessary, and weeds retarded irrigators. Very shortly now this field will speed up in area irrigated per man day."

PLANT FIELD NO. 40—STARTED FEBRUARY, 1928. SEEDLING AREA. LEVEL LAND—33.89 ACRES

	Round No. 1	Round No. 2	Round No. 3	Round No. 4	Round No. 5
Total Water..............	3,166,294	2,782,767	2,312,564	3,244,250	3,868,829
Acre Inches per Acre.....	3.47	3.05	2.535	3.525	4.204
Gallons per Man Day.....	52,396	57,914	60,459	66,548	67,874
Acre per Man Day........	0.556	0.699	0.878	0.695	0.594

Fields 8A and 8B are ratoon fields changed to the new system immediately after harvesting. Water figures are not available, but the following data on area covered per day show how soon it is possible after starting the field to maintain a large area per man day irrigating in spite of the fact that some weeding had to be done.

ACRES PER MAN DAY

Round Number	Field 8A	Field 8B
1	0.911	0.904
2	0.867	0.904
3	1.367	0.961
4	1.555	1.318
5	1.804	1.464
6	2.405	1.564

There are many obvious advantages to the Koloa system of irrigation:

1. *Economy of Labor:* The striking point in the data available on the Koloa system is the large area covered by each irrigator. Under the furrow system now in general use, one acre per man day is considered a fair average, and in many cases the area covered per day falls far below this figure. The Koloa system, in mature cane, averaged 3.72 acres per man day. This result is possible because of the large stream handled by the irrigator.

2. *Economy of Water:* A more economical application of water is possible with the Koloa system. Under the usual method of furrow irrigation the low flow, resulting in greater percolation loss as well as loss of head in heavy cane, makes an application of from 4 to 10 acre inches per acre necessary. Half this amount is used by the Koloa system.

3. *Even Distribution:* The large flow causes the entire line to be filled quickly and uniformly. There is less percolation loss at the head of the line than there is with the small flow of the furrow system. All of the water admitted to the line is retained, as the high spillway prevents the return of the water to the watercourse.

4. *Elimination of Panis:* The use of the portable pani removes the necessity of using from twenty to fifty opala panis per watercourse, as is now the case with the furrow system. Not only is a considerable item of expense in preparing the panis and consequent delay in irrigation eliminated, but seepage from poorly constructed dams is removed.

5. *Treatment of Plant Fields:* Danger of washing out lines in irrigating plant fields is lessened by use of the Koloa system. The end of the bag pani may be placed on top of the spillway and the water diverted over it into the furrow. In this way the head of the line is not eroded, and the spillway soon becomes firm and compact. It is advisable in early irrigations of plant cane to place the pani so that water is diverted into one line only and then into the other. It is necessary, of course, to use a much smaller stream in irrigating young plant.

6. *Better Supervision:* With the Koloa system it is necessary to push the cane away from the watercourse after a few months' growth. This procedure increases the efficiency of the irrigator, and insures closer and more rapid supervision.

The only apparent drawback to the Koloa method of irrigation is the possibility that, because of the large stream used, the watercourses and lines may be eroded to some extent, especially on pali land.

The objection that it is impossible for the irrigator to weed and strip as he irrigates is a negligible one, as the economy of labor in irrigating more than offsets the extra labor required for separate weeding and stripping operations. It has been definitely proved by innumerable experiments and observation that the efficiency of the irrigator is greatly lessened when he is forced to weed and strip as he works.

Fig. 2. View of pani framework.

Fig. 3. Upstream view of pani in place.

Fig. 4. Downstream view of pani in place.

Watercourse Layout

Koloa System Of Irrigation

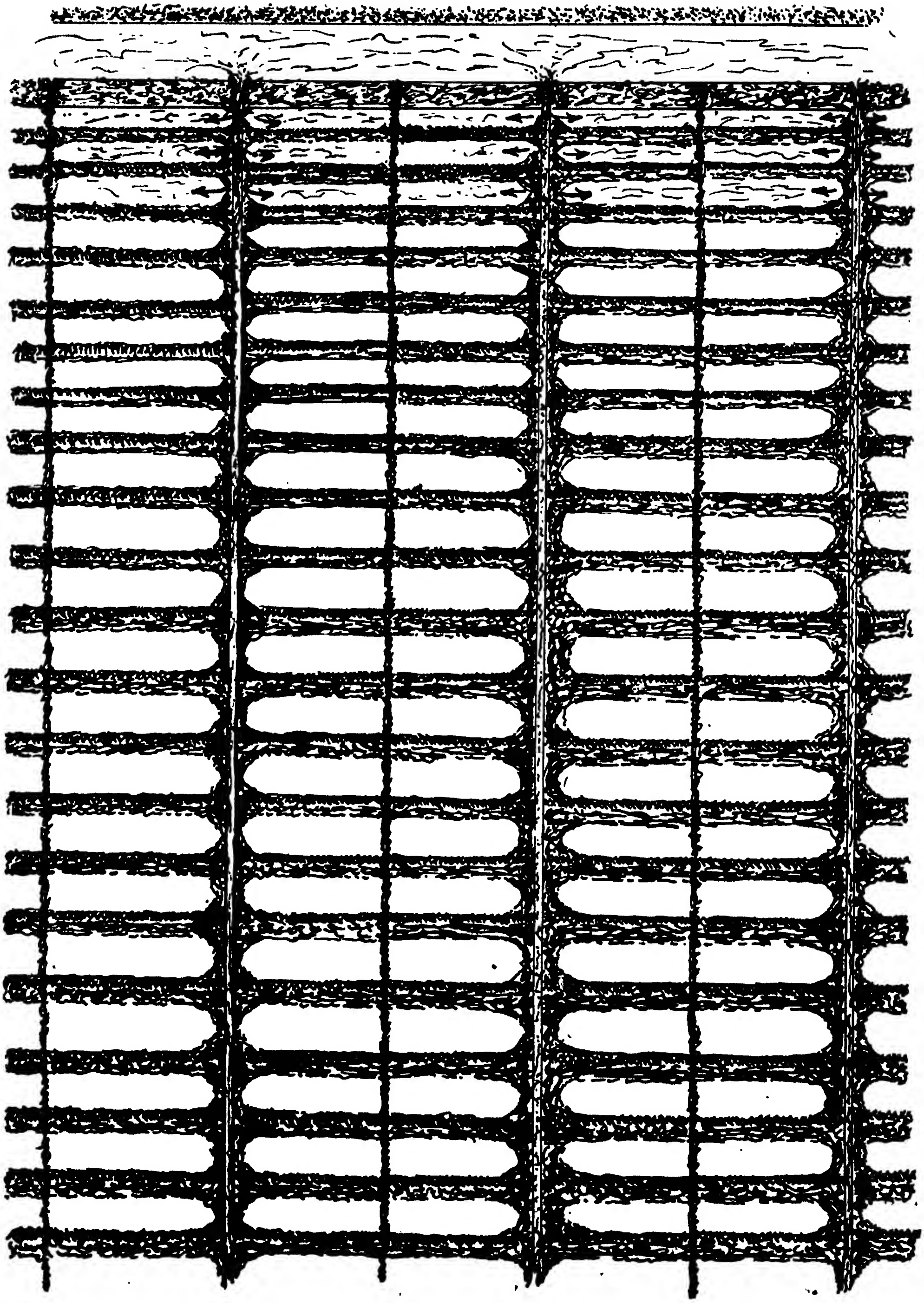


Fig. 5

How Are We to Recognize a Super Cane?

By J. A. Verret and A. J. Mangelsdorf

To produce seedlings is no longer difficult. Methods of making crosses and germinating the seed have been developed to a point where seedlings of a desired combination can be obtained in large numbers at low cost, if both parents are reasonably fertile.

The outstanding difficulty at the present time is the matter of determining which seedling, of the large number produced each year, is the most profitable one for a given set of conditions.

In the past, much of the selection work throughout the Islands—too much of it, we believe—has been carried on somewhat as follows. When new seedlings are received from the Station, or from other plantations, the seed is planted out, often without check lines of the standard variety with which to compare them. In due course those which look promising are "spread" again, often without check plots of the standard variety. If a given seedling continues to present an attractive appearance it is multiplied further, and in time may come to occupy a considerable acreage, without having been subjected to a single yield test which might have been expected to give reliable figures on cane tonnage or sucrose content; that is to say, in comparison with the standard cane planted at the same time in adjoining plots. Meanwhile, the seedlings not so attractive in appearance have been discarded, again often without a single reliable figure to warrant the action.

Appearance is a sufficiently safe basis on which to discard the conspicuously inferior seedlings. However, when it comes to determining differences of only 10 to 20 per cent, judgment based on mere appearance becomes a matter of guesswork. One can easily satisfy himself on this point by attempting to guess the yields of a number of small plots of one of the standard varieties and then weighing these plots to check up on his guesses. If it is difficult to be sure of a 10 per cent difference in small plots of one and the same variety, how much more difficult is it to determine by observation the relative yields of different varieties with different growth habits and differences in sucrose content. The answer is that it can't be done; at any rate, not by many of us.

Yield figures from a *poorly planned* experiment, however, may be just as misleading as conclusions based on observations. Without check plots to detect soil variation, the highest yielding seedling is too often the one in the most favored spot rather than the inherently superior one.

The only safe procedure, we believe, is to plant the aspirants to the heavyweight championship in checkerboard plots, comparing their yields with adjacent check plots planted to the present title holder. Neither should this comparison be merely a visual one based on appearance. Except for the obviously inferior ones, actual weights and juice determinations should be recorded. Where a complete

juice analysis of each seedling is not practicable, a very good approximation of quality ratio may be had from a refractometer reading of a small sample expressed by means of a pair of pliers from sections of a number of sticks. This method is described in greater detail in another paper in the present number of the *Record.*

Observation notes are, nevertheless, an important and valuable adjunct to yield figures. Many of the habits and qualities of a seedling may be brought to light only by repeated observation, and notes taken at various stages of growth are extremely useful. They should, however, be used as supplementary to and not as a substitute for actual harvesting figures.

Seedling Testing in Java

The rapid multiplication of the Java supercane P. O. J. 2878 from a single stool in 1922 to over 300,000 acres in the last crop is now a familiar story. Instead of depending on observations over a period of years to discover their superior canes, the Java planters try out their promising seedlings, as soon as seed is available, in trial plots checkerboarded with plots of their standard cane. With reliable yield figures from these sources at hand, they are able to decide promptly whether to discard a given seedling or whether to spread it as rapidly as possible.

The rapidity with which P. O. J. 2878 was spread points to the efficacy of their system of testing.

In 1924, two years from the time that only a single stool of P. O. J. 2878 existed, there were planted in different parts of Java fifteen semi-final and final tests, each with four or more replications and with alternate plots of the standard variety. When these tests were harvested in 1925, it was found that this cane had outyielded its competitor in thirteen of the fifteen trials. During the same year P. O. J. 2878 was included also in thirty-eight preliminary trials and in twenty-nine of these it outyielded its competitor.

The next year (1926) P. O. J. 2878 was tried against their standard canes in 254 semi-final and final trials. In 238 of these it outyielded its competitor.

In 1927 it was included in 847 trials, in 724 of which it occupied first place.

Having at hand the figures from so many experiments, each laid out in such a manner as to give reliable results, the Java planters had good reason to feel that they were safe in spreading the new supercane as rapidly as possible. Had they been relying on mere observation, the adoption of this cane would certainly have proceeded much more slowly, with a loss to Java in the meanwhile of thousands of tons of sugar a year.

Java harvested last year, in addition to large numbers of preliminary trials, 1055 semi-final and final trials. These were all checkerboard tests, each with from four to twelve replications.

Java's crop totals something over 450,000 acres of cane each year. This means a semi-final or final variety test for each 400 acres.

If our seedling testing were on a similar scale, we would be harvesting, with our yearly crop of around 125,000 acres, something like 300 semi-final and final yield trials, whereas up to the present we have averaged scarcely a half dozen

a year. We are speaking, of course, of checkerboard tests with replications, comparable to our fertilizer tests.

When we reach Java's level in seedling testing, a large plantation cutting, say, 6,000 acres of cane a year will be harvesting yearly around fifteen variety tests, each with four or more replications.

Proposed Seedling Testing Program for Hawaii

In an effort to reduce in the future the proportion of variety tests which may give misleading or at best indecisive results, the agricultural department issued to its members several months ago a memorandum on plot arrangement in variety testing. This memorandum is reproduced below. Obviously it cannot be final, but must undergo revision as our knowledge of the problem increases.

We submit it, however, as the best procedure we are able to offer at the present time. Any suggestions as to its improvement will be welcomed by the agricultural department.

Plot Arrangement in Variety Testing:

Variety Tests as employed in these Islands may be classified as:

1. Preliminary Trials.
2. Semi-final Trials.
3. Final Trials.

Each of these will be discussed separately.

1. Preliminary Trials

This form is used for Field Trials 2 and 3 of new seedlings and for first trials of seedlings newly introduced from other localities.

Since the number of seedlings to be tested in preliminary trials is usually large and the amount of seed limited, replications are not ordinarily desirable.

The size of the individual plots may vary from 10 to 200 feet of line, depending upon the amount of seed available, and upon the degree of promise of the seedling in question.

It is preferable to have alternate plots planted to the standard variety. However, if the soil is quite uniform, and space is limited, the number of checks may be reduced to one in three without serious loss of accuracy.

Guard rows of crop cane are used to separate the variety test from roads, level ditches and other disturbing factors.

The plots should be as nearly square as possible, in order to reduce to a minimum the competition between varieties which occurs along the borders of the plots.

While the size, shape and arrangement of the plots must necessarily be governed somewhat by such considerations as the contour of the land, the irrigation system, and convenience in planting and harvesting, the principle illustrated in Fig. 1 should be adhered to as closely as practicable.

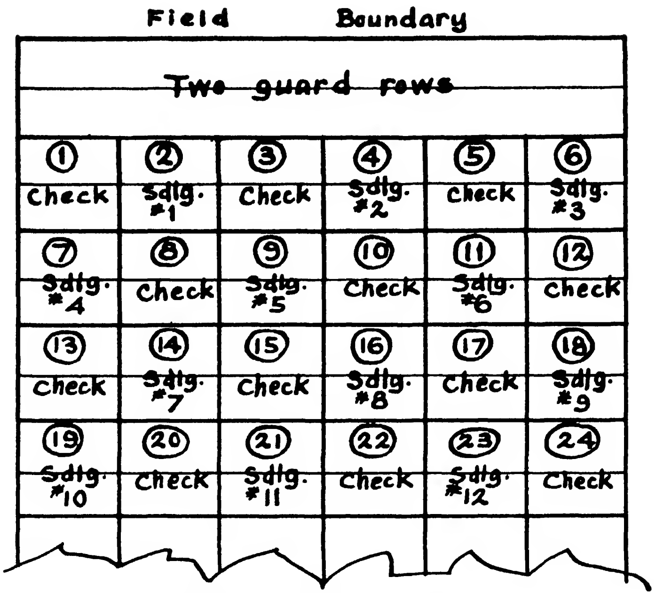


Fig. 1. Model plan for preliminary trial.

Number of plots: One of each seedling, alternating with check plots of the standard variety. If the soil is very uniform, one check plot to two plots of seedlings may be sufficient.

Size of plots: Ten to 200 feet of line.

Shape of plots: Preferably square, in order to reduce to a minimum the effect of competition along plot borders.

Guard rows: Experiment to be separated from roads, level ditches and other disturbing influences by guard rows.

Numbering of plots: Each plot numbered, to facilitate identification.

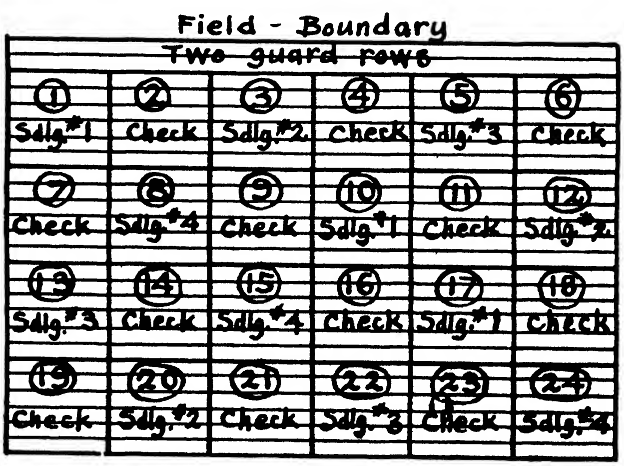


Fig. 2. Model plan for semi-final trial.

Number of plots: From two to four of each seedling, alternating with check plots of the standard variety.

Size of plots: From 1/20th to 1/50th acre, preferably an area large enough to fill a car.

Guard rows and shape of plots: As indicated for Preliminary Trial.

2. *Semi-Final Trials:*

Only varieties which in preliminary trials have shown themselves to be promising should be included in a semi-final trial.

As in the preliminary trial, alternate plots are check plots planted to the standard variety.

Each seedling should be replicated from two to four times. The size of plot may vary from 1/20th to 1/50th acre. The number of replications and size of plot will depend somewhat upon the amount of seed and space available, and upon the degree of promise of the seedling in question.

Fig. 2 illustrates the conventional form of a semi-final test. In this test, Seedlings 1, 2, 3 and 4 are being tested in comparison with alternate check plots of the standard variety. Each of the four seedlings is replicated three times.

As in the preliminary trials, practical considerations may require some changes in detail, but the plan should be followed in principle.

3. *Final Trials*

Only seedlings which have given a good account of themselves, in both preliminary and semi-final trials should be included in a final trial.

Alternate plots are checks of the standard variety. Each seedling should be replicated from five to seven times. The size of plot may vary from 1/10th to 1/20th acre.

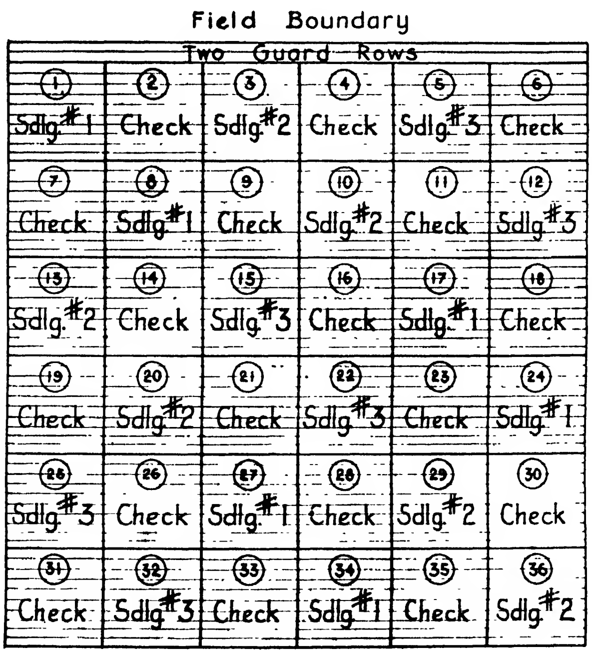


Fig. 3. Model plan for final trial.

Number of plots: **From five to seven of each seedling, alternating with check plots of the standard variety.**

Size of plots: **From 1/10th to 1/20th acre.**

Shape of plots: **Necessarily dependent upon contour of field, preferably as nearly square as possible. Very long, narrow plots may be used to good advantage under unirrigated conditions if the outside rows of each plot are discarded as guard rows.**

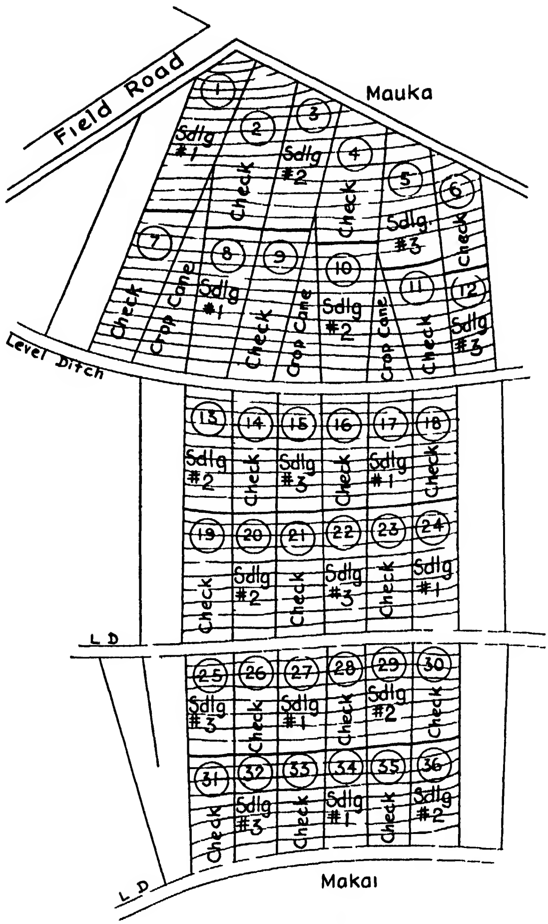


Fig. 4. Final trial in an irrigated field.
Hapa watercourses are discarded.
Each plot is numbered to facilitate identification.

A conventional arrangement is shown in Fig. 3 Here Seedlings 1, 2 and 3 are being compared with alternate checks of the standard variety. Each of the three seedlings is replicated six times.

Fig. 4 shows the adaptation of the conventional plan to an irrigated field.

Under irrigated conditions the locations and boundaries of the plots are determined more or less by the ditches and watercourses. Under unirrigated conditions it is easier to adhere to square plots, regularly placed.

Long narrow plots are also suitable for unirrigated fields with long lines because of their convenience in planting and harvesting. When they are used, however, the outside lines of each plot should be discarded from the experiment when it is harvested, since their yields are likely to be affected either favorably or adversely by the adjoining lines of the neighboring variety.

A single trial with only five to seven replications is, of course, "final" in name only. Final conclusions can only be drawn from a number of such trials carried out in different parts of the area for which the seedling is intended, and over a number of years. More conclusive results could be had in a given experiment

by increasing the number of replications. The results thus obtained, however, might apply only to that particular area and to weather conditions exactly like those experienced during the trial. For this reason the combined results from two trials, each with six replications, and planted in slightly different areas, or in different seasons, are less likely to be misleading than the results from a single trial with twelve replications.

General Considerations

1. *Location of Variety Tests:*

If variety tests could be placed in areas so uniform that all plots when planted to the same variety would give exactly the same yield per acre there would be no need of replications, and a single check plot of the standard variety would be sufficient.

The first consideration, therefore, in choosing an area for field experiments is uniformity. This is especially important in pot seedling areas and in preliminary trials, for in these cases it is impossible to have replications to help offset the variability.

It is better to delay an experiment until a reasonably uniform area is available than to plant it on a broken, spotty or highly variable area.

W. W. G. Moir has called attention to the fact that it is undesirable to place a variety or fertilizer experiment in an area recently occupied by an experiment involving different varieties or soil treatments.

A second consideration in locating variety tests is that of convenience. They should be so situated and so arranged as to interfere as little as possible with plantation routine in planting and harvesting.

2. *Ratooning:*

Yields from at least one, and preferably two or three ratoon crops, in addition to the plant crop, should be recorded before the experiment is abandoned.

3. *Quality of Seed:*

A good stand on all plots is essential to reliable figures. If the supply of good seed is limited, it is better to reduce the size of plots or the number of replications than to use poor seed or to increase the spacing.

Every effort should be made to have seed of the same kind for all varieties and checks in the test. If body seed is used for the seedlings, body seed of the same age should be used for the checks whenever possible.

Notes should be taken on the stand of each plot within a month or two after planting, so that these facts will be at hand when the yield figures are being considered.

Good seed is often unobtainable for first plantings. Sometimes the seed must be obtained from other localities, with consequent damage in handling. Due allowance must obviously be made in evaluating the results under those conditions. In general, the check plots in first plantings of seedlings from other localities should be used as indicators of soil variability rather than as absolute standards which the seedling must surpass in order to be retained.

4. Check Plots:

Whenever we record the yield of a seedling on a given plot, the question arises: "What would the standard cane have yielded had it been growing on that plot?" The nearest approach to an answer to this question can be had from plots of the standard immediately adjacent to this seedling plot.

It is felt that whenever a seedling is planted, a check plot of the standard variety should be planted at the same time and adjoining the seedling. In the absence of replications, check plots afford the only reliable basis of comparison upon which to measure the performance of a seedling.

Even when seedlings are planted out primarily to increase the supply of seed, check plots of the standard are not amiss. Every opportunity should be seized upon to observe the performance of all seedlings which are being carried along. This can only be done satisfactorily when the seedling plots are interspersed with check plots.

5. Size of Plot:

In variety testing there are several advantages in small plots of the size indicated, as against larger plots. First, the amount of planting material of the newer seedlings is usually limited. Second, increasing the size of the plot and thus including more area inevitably results in increasing the variability of soil conditions within the experiment.

If seed and space are limited, larger plots can only be had by decreasing the number of replications. This is undesirable. It is obvious that in the long run five 1/20th acre plots checkerboarded with similar plots of the standard variety will give more reliable yield figures than a single pair of plots of 1/4th acre each.

6. Number of Lines per Plot:

Under unirrigated conditions, because of the practice of piling the cane from two lines together in the intervening furrow at harvesting time, all plots should contain an even number of lines, whenever possible.

7. Guard Rows:

In the earlier trials, with their smaller plots and fewer replications all seedlings cannot be subjected to equal field boundary and level ditch effects. It is, therefore, better to eliminate these effects altogether by means of guard rows. In later tests guard rows along level ditches may be unnecessary if care is taken to see that all seedlings are equally exposed to their effects.

8. Harvesting:

All plots must be weighed and analyzed separately. "Lumping" either the cane yields or the juice samples from the different plots of a variety destroys much of the information to be gained through replications.

9. Staking of Plots:

It is important that the plots be staked with permanent stakes in such a manner that anyone inspecting the area may identify each seedling at a glance. It facilitates the taking of notes, and stimulates the interest of the plantation personnel in the seedlings.

The plots in the area should be numbered, so that each plot has a distinguishing number which appears both on the map and on the field stake. The plot number, as well as the seedling number, should be recorded in tabulating yields and juice analyses. The plot number serves to locate the exact position in the field of the check plot or replication in question.

10. Samples for Juice Analyses:

Yield tests which are otherwise accurate may be rendered false and misleading by inadequate samples for juice analyses. A running sample of the crusher juice from the entire lot of cane as it passes through the mill is probably most satisfactory. If this is unobtainable, a large sample of 150 to 200 pounds from each plot should be used. Samples smaller than this are in great danger of being unrepresentative. Care must be exercised in drawing the sample in order that it may be as nearly a true average as possible in the matter of age and quality. The cane which goes into it should, of course, be drawn from each part of the plot.

11. Accuracy:

Errors which would be negligible in large scale field operations may have considerable effect when dealing with small plots. Care must be taken that areas are measured and yields determined with the necessary accuracy.

12. Interpreting the Results:

The generally accepted method of arriving at the dependability of figures from yield tests is that of "Student." The method is set forth in a table prepared by Y. Kutsunai, a copy of which may be had from the Station upon request.

Summary

1. We have been basing the selection and elimination of seedlings to too great an extent on appearance.
2. Many of our present seedling areas are laid out in such a manner that they cannot be relied upon to give decisive figures, because they do not include enough check plots to determine whether the high yielding seedlings are so because of inherent superiority or because they are in a favored location.
3. Java does not depend on observation. Instead, it looks to data from yield trials to determine whether a seedling is to be spread or rejected.
4. A program of seedling testing for Hawaii is outlined.

The Hand Refractometer as an Aid in Seedling Selection

By J. A. Verret and A. J. Mangelsdorf

The production of large numbers of new seedlings each year has as its prime object the discovery of a cane which will produce more sugar per acre than those now grown. Because of the fact that it is invisible we are rather prone to forget that the source of our revenue is the *sugar* in the cane—not the cane itself.

It is unfortunate, but nevertheless a fact, that we can form no estimate of the sucrose content of a seedling from its appearance. It is important, therefore, to have a simple and rapid means of estimating the juice quality of the thousands of seedlings examined each season. Without some such means we are compelled to ignore in our early selections the very constituent for which we are breeding.

In the earlier stages of selection (Field Trials 1 and 2) each seedling is represented by a single stool, or by a few feet of line. A method of arriving at juice quality must, therefore, provide a means of obtaining a sample without destroying too much of the cane, for as much seed as possible of the seedlings selected must be saved for planting.

A few months ago Carl Zeiss, Inc., New York, announced a new hand refractometer designed especially for the determination of per cent solids in solution in small samples of beet or cane juice. One was purchased by the Station, and it has proved to be very satisfactory for our purpose.

A brief description is given of the method in which it is used.

The use of the refractometer to form an estimate of juice quality in seedlings is not new. The Manoa Substation is not equipped with a testing mill and laboratory, and Mr. Kutsunai has for some years been using an ordinary laboratory refractometer in arriving at the yields of his Field Trial 2 and Field Trial 3 plots. The new refractometer, however, and certain changes in the manner of sampling, have made it possible to speed up this phase of the work.

The following procedure is now being used in making selections in Field Trial 1. The seedlings are classified, preferably by several judges working independently, into three groups:

1. Those which are outstanding enough to be retained for a second trial regardless of their juice.
2. Those which are to be retained if the juice is satisfactory; and finally,
3. Those which are too poor to consider. No juice samples are taken of this group.

The canes which are placed in the first two groups are numbered and tagged. Small segments are then cut from the five largest stalks in the stool, by means of a light backsaw (dovetailing saw). The saw is equipped with a guard, which determines the depth of the cut. This guard, which greatly facilitates the sampling, was devised by J. P. Martin. With two quick strokes of the saw the segment which serves as a sample is removed from the middle of the stalk and is placed in a vial. As already mentioned, five sticks are so sampled. The vial, with its five samples, is then taken to the portable "field laboratory." Here five drops of juice are expressed from each segment by means of a pair of pliers. The juice is collected in a small crucible, and a single reading is made on the composite sample from the five sticks.

The entire operation consumes less time than is required to describe it. Three men, one cutting the samples, one reading the refractometer, and a third recording the figures, have made 1,500 determinations in seven hours.

The new hand refractometer lends itself to rapid work because, unlike the old laboratory type, the reading is made without any movement of the eyepiece. One

Fig. 1. Sampling a standing stool. (Field Trial 1.) A small segment is cut from each of five sticks by means of a light saw equipped with a guard which determines the depth of the cut. A refractometer reading is then made on the juice, which is expressed from the sample by means of a pair of pliers.

Fig. 2. Portable field laboratory designed by Y. Kutsunai. The juice from the five samples has been collected in a small crucible and is being poured onto the prism of the hand refractometer.

Fig. 3. Making a reading with the hand refractometer in the field.

simply places several drops of the juice on the prism, closes it, and reads the scale at the point where the shadow crosses.

The fact that it is light and compact recommends the new hand refractometer for field work. It is no more difficult to carry than a pair of field glasses. It costs only about one-third as much as the old laboratory model.

The refractometer reading gives, of course, only the per cent solids in solution in the juice. This determination corresponds to the "Brix" of the juice as determined by the spindle hydrometer. The refractometer has been found to be more accurate than the Brix spindle for rapid approximations, because the spindle may be as much as several per cent in error if read before the captured air bubbles in freshly extracted juice have had an opportunity to escape, whereas these bubbles have no perceptible effect on the refractometer reading.

The objection might be raised that per cent solids without any knowledge of purity is an inadequate basis on which to judge the quality of the juice. Studies on the relation between per cent solids (Brix) and quality ratio in a large number of seedlings are reported in detail in another paper in the present issue of the *Record*. It need only be mentioned here that these studies show a close relationship not only between per cent solids and sucrose, but also between per cent solids and purity, resulting in a very high correlation between per cent solids and quality ratio. The relationship is sufficiently close to warrant the use of per cent solids as determined by a refractometer reading in forming a preliminary estimate of juice quality in the early stages of selection.

The method of sampling described has the advantage that the sticks from which the samples are taken are left standing and may be used as a source of seed. A certain percentage of them may blow over if subjected to wind, but unless broken off entirely, which rarely happens, they continue to live indefinitely.

Various means of removing a small sample from the stalks were tried before the backsaw method was adopted. This method is rapid and positive, but there is still room for improvement. It should be possible to devise an instrument which will remove a sample without severing so much of the rind, and, therefore, with less danger of the stick breaking following sampling.

Some such method, if perfected, should prove useful as a means of obtaining pre-harvest samples of fields which are being ripened off. It is possible that even the present backsaw method of sampling would answer the purpose. It would seem that a sample composed of sections cut from a large number of sticks should be more representative than a few sticks. In the time required to cut a five-stick sample and carry it out of the field, several hundred sticks could be sampled with a backsaw. The sampler would need to be provided with a suitable container into which the segments could be dropped quickly and in which they would be protected from evaporation. When a sufficient number had been collected the juice could be expressed by means of a small press. Several hundred segments should yield enough juice for Brix, polarization and glucose determinations. It is planned to try this method of pre-harvest sampling on a field scale the coming season.

Summary

1. In the early stages of selection, where thousands of seedlings are dealt with, a rapid means of estimating juice quality is needed.

2. Per cent solids (Brix) has been shown to be highly correlated with quality ratio, and may, therefore, be relied upon to give a good estimate of juice quality.

3. A rapid method of sampling standing cane and of determining per cent solids by means of the new hand refractometer is described.

Notes on Irrigation Investigations and Control at Makee Sugar Company

By H. R. Shaw

Plantation Irrigation Equipment

Supply: Mountain flow supplies the irrigation water for the Makee plantation. The plantation develops from 300 to 600 million gallons of water per month from stream and storm ditch sources, and purchases approximately 7,500 million gallons per year from other sources outside the plantation.

One combination Diesel centrifugal pump with a six million gallon capacity pumps the mill discharge water to the upper levels of the plantation for use in irrigation.

Field Layout: The plantation practices the usual Hawaiian furrow system of irrigation. Although there is no standard practice as to the number of lines irrigated as a unit, the two-line "U" system is generally used. Watercourses are 35 feet wide, and furrows are 5 feet wide from center to center.

Survey: All fields are gross acreage with the boundary 3 feet out from the actual cane boundary. Watercourse surveys are from center of watercourse to center of watercourse and from center of level ditch to center of level ditch.

Ditch Lining: None of the plantation ditches are lined, and as yet no seepage tests have been made.

Water Measurements

Control: The staff conducting irrigation measurements, investigations and control consists of one man in charge, one clerk, and two men who handle growth measurements, repair and maintenance of meters, and assist in harvesting experiments. Meter readings are submitted by the section overseers from data supplied by the field ditchmen. The ditchmen also make all adjustments and changes of orifice gates.

Equipment: Weirs with Stevens Water Stage Registers measure the water in the main supply ditches. Rated sections are used in sections where it is impossible to install weirs.

Forty Great Western (Lyman) meters are used in all field installations. Redwood installations with depressed "V" basins with a 14-inch drop, 36-inch flat bottom, and 18-inch clearance at both ends, are rapidly taking the place of the flat-bottomed installations previously used.

J. M. Watt, assistant manager, and formerly in charge of irrigation investigations at Ewa, Lihue, Koloa and Makee, is one of the strongest advocates of the Great Western meter in the Islands. He says: "This meter is adapted to a certain purpose, and when used under the conditions required and for the purpose intended, it will give excellent results. It is not built for registering high fluctuations in head, and a flow recorder should supplement the meter on main supply canals. For measuring total water to the fields, however, it is decidedly preferable to any other device on the market. Its main advantages are: simplicity of construction, ease of operation, sensitiveness, portability, and the fact that only a small quantity of the total flow is required to pass through it, thus allowing easy screening. From an exhaustive series of tests in field installations and against standard rectangular weirs, I have found that the Great Western meter will check to within 3 per cent, which is all that is necessary to supply a working average on water distribution, man capacity, and other factors of interest to the plantation."

Irrigation Investigations

Policy: The general policy of the plantation management in regard to irrigation investigations is to expand the program of complete metering of the plantation as rapidly as possible, supplemented by a limited amount of experimental work. Makee also plans to establish an irrigation control system.

Irrigation Experiments: The area of the plantation under irrigation control is as follows:

	1927 Crop	1928 Crop	1929 Crop
Experiments	134.12	76.56	98.06
Total Application	227.95	735.64	530.05

Irrigation experiments are based on the interval between irrigations. Three general series of treatments are given, depending on the soil and climatic conditions:

Day Interval

Maximum	Normal	Minimum
7	14	21
10	17	24
10	20	30

Each treatment is applied to level ditch plots with three repetitions in each experiment. Net water is measured at the head of the level ditch, growth measurements are taken on at least 25 stalks in each level ditch plot.

During the second season growth period, Makee employs a ripening schedule with gradually lengthening intervals for each treatment. The harvesting date and date of last irrigation are predetermined, and a ripening schedule for each treatment is so designed that at the last irrigation all plot treatments have the same interval of 24 days.

According to Mr. Watt, a reasonable interval schedule for Makee conditions would be:

Short Crop

From start of crop to following September—10-day interval (max.).

From September to November—17-day interval (normal).

From November to March—24-day interval (min.).

From March to cessation of irrigation—17-day interval with gradually increasing interval up to start of ripening period.

Long Crop

Same as for short crop, except that the maximum treatment would continue through the summer of the second season before applying the ripening schedule.

Experimental Results: Harvesting results from the irrigation experiments tend to confirm conclusions drawn by other plantations on the Island:

1. Cane tonnage generally increases with the amount of water applied. With heavy applications, however, the yield is not in proportion to the units of water per unit cane.

2. The more rapid and uniform the irrigation the better the results in growth and total sugar.

3. The longer the interval the less acreage covered by each irrigator per day, and the greater amount of water consumed per acre.

4. In general, the response of growth to frequent applications of water is not as marked in the second growth season as in the first.

Seedling Selection Studies—I

INTERRELATIONSHIPS BETWEEN BRIX, PURITY AND QUALITY RATIO

By J. A. Verret and A. J. Mangelsdorf*

In Field Trial 1, each seedling is represented by a single stool and in Field Trial 2 usually by only a few feet of line. Thousands of seedlings have to be dealt with in these early stages of selection before the process of elimination has reduced their numbers.

* Thanks are due Royden Bryan, J. F. Jensen, Asao Doi and R. H. Rice for assistance in tabulating the data and making calculations.

Because of the fact that there is only a small amount of each seedling, and because there are so many to be examined, a complete analysis to determine the quality of the juice is hardly feasible. Brix determinations on small samples have therefore been resorted to as a means of estimating the juice quality of the seedlings in these early stages of selection.

In order to form an opinion as to whether a Brix determination is a sufficiently reliable basis on which to estimate quality ratio under these circumstances, the complete juice analyses of several thousand different seedlings were examined statistically, in order to determine (1) the relation between Brix and purity and (2) the relation between Brix and quality ratio. The findings are presented below:

Brix and Purity

The term "Brix" is used throughout in referring to per cent solids in solution, whether determined by a Brix spindle or by a refractometer.

Purity refers, of course, to the percentage of sucrose in the total solids in solution.

RELATION BETWEEN BRIX AND PURITY
Correlation Table
Data from analyses of 948 seedlings harvested in 1917

Brix \ Purity	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
12	1	2	1	2			1																	
13		1	1	3	3		1	3	4	2	1													
14					2	1	5	6	9	11	16	15	3	7	1	3	1							
15								3	2	8	9	27	22	23	32	21	7	3	3				1	
16										1	2	9	22	28	47	36	36	36	28	5	2			
17												1	3		6	21	32	35	49	39	22	4		
18																1	4	6	18	39	35	24	9	3
19															1				3	8	17	19	8	1
20																			1	3	3	2	3	
21																							2	

Fig. 1

We were surprised to find that a very high positive correlation exists between Brix and purity. Fig. 1 shows a correlation table setting forth the relationship between these two variables in a group of 948 seedlings harvested at Makiki in 1917. It will be noted on referring to the illustration that at 13 to 14 Brix, for example, the purity ranges from 72 to 82, while at 20 to 21 Brix the purity ranges from 89 to 94. The coefficient of correlation between the two was found to be $+ .82 \pm .007$. The coefficient of correlation is useful only in so far as it enables us to visualize from a single figure (with its probable error) the relationship existing between two sets of values, each set containing perhaps several hundred items.

It will be remembered that a coefficient of $+ 1.0$ indicates complete positive correlation, i.e., with the two variables increasing in exactly the same proportions; that a coefficient of 0 indicates that the two variables behave quite at random towards each other, and that a coefficient of $- 1.0$ indicates complete negative correlation, the one value increasing proportionately to the decrease of the other.

In the case under discussion, therefore, the correlation is a very close one, especially in view of the small probable error.

The coefficient of correlation between Brix and purity was calculated for two other groups of seedlings also, with the following results:

644 seedlings harvested in 1918.............. $+.72 \pm .01$
492 seedlings harvested in 1921.............. $+.85 \pm .008$

It will be noted that for these two groups also the coefficients of correlations are very high, with small probable errors.

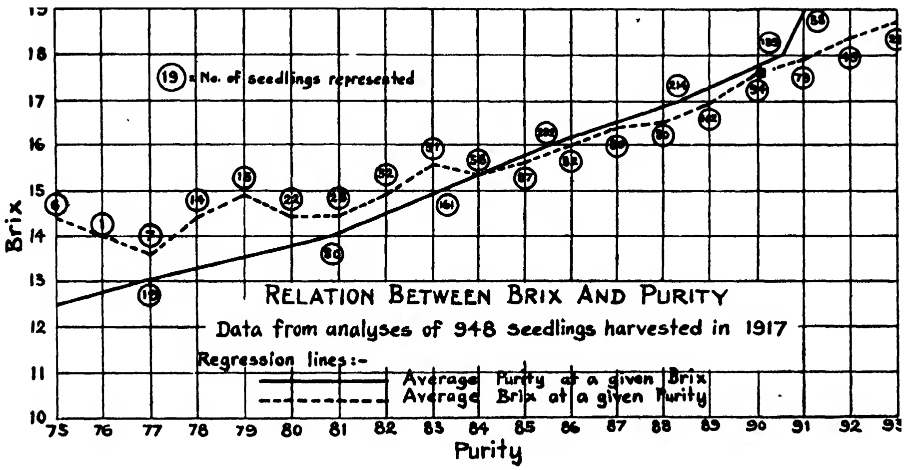


Fig. 2, dealing with the same group of seedlings as Fig. 1, sets forth in a different manner the relationship between Brix and purity. The broken line gives the average Brix at a given purity, the solid line the average purity at a given Brix. If the correlation were perfect the two lines would coincide. It will be observed that they do, in fact, follow very nearly the same course.

It is not obvious why there should be such a close correlation between Brix and purity. It is conceivable that canes with a high percentage of solids in solution might have, on the average, just as large a proportion of those solids in the form of non-sucrose materials as those with a small percentage of solids. Such, however, is not the case. The greater the percentage of solutes in the juice, the greater the proportion of sucrose to impurities.

It would not have been so surprising to have found a definite relationship of this kind among a number of analyses of a single cane, say H 109. We did not anticipate its existence, however, within a group of miscellaneous seedlings involving a number of parentages.

That a similar relationship to that just described also holds within a single variety was shown by a study of juice analyses of 947 stools of H 109 cane harvested at Waipio in 1927. The coefficient of correlation between Brix and purity was found to be $+.65 \pm .01$. This correlation, it will be observed, is less pronounced than for the three groups of data already discussed, each member of

which was a different seedling. Why the correlation within a single variety should have been lower than among different seedlings, we are unable to explain, unless it is that conditions are more variable in Field 21, Waipio, where the H 109 stools were grown, than at Makiki where the miscellaneous seedlings were grown.

Brix and Quality Ratio

That a certain amount of correlation between Brix and quality ratio must inevitably exist is obvious, since a juice with a low Brix cannot have a high percentage of sucrose.

This fact, together with the further finding, already discussed, that a low Brix tends very definitely to be associated with a low purity, made it appear likely that the correlation between Brix and quality ratio is a high one.

This was found to be the case in the three groups of seedlings examined, as will presently be shown.

RELATION BETWEEN BRIX AND RECOVERABLE SUCROSE

Correlation Table

Data from analyses of 948 seedlings harvested in 1917

Percent Recoverable Sucrose \ Brix	11.0–12.0	12.0–13.0	13.0–14.0	14.0–15.0	15.0–16.0	16.0–17.0	17.0–18.0	18.0–19.0	19.0–20.0	20.0–21.0	21.0–22.0
3.0–4.0	1										
4.0–5.0											
5.0–6.0	2										
6.0–7.0		3	7								
7.0–8.0		1	11	10							
8.0–9.0			2	46	20						
9.0–10.0				12	102	19	1				
10.0–11.0					35	149	10		1		
11.0–12.0					2	62	147	5			
12.0–13.0							67	79	4	1	
13.0–14.0						1		52	45	1	
14.0–15.0									15	11	1
15.0–16.0											3

Percent Recoverable Sucrose

Brix

Fig. 2

For plotting purposes, quality ratio must be converted into its reciprocal, per cent recoverable sucrose, because a unit of quality ratio is not a constant one. A difference of a point at a quality ratio of 6.0 is twice as large in terms of per cent sugar as a difference of a point at a quality ratio of 12.0. In these studies quality ratios have therefore been converted into per cent recoverable sucrose for the sake of accuracy in plotting.

Fig. 3 shows the relation between Brix and per cent recoverable sucrose among the 948 seedlings harvested in 1917. It is obvious from the distribution of the values on the illustration that the correlation is very close. A given Brix tends to have a definite per cent recoverable sucrose, with but little departure in either direction.

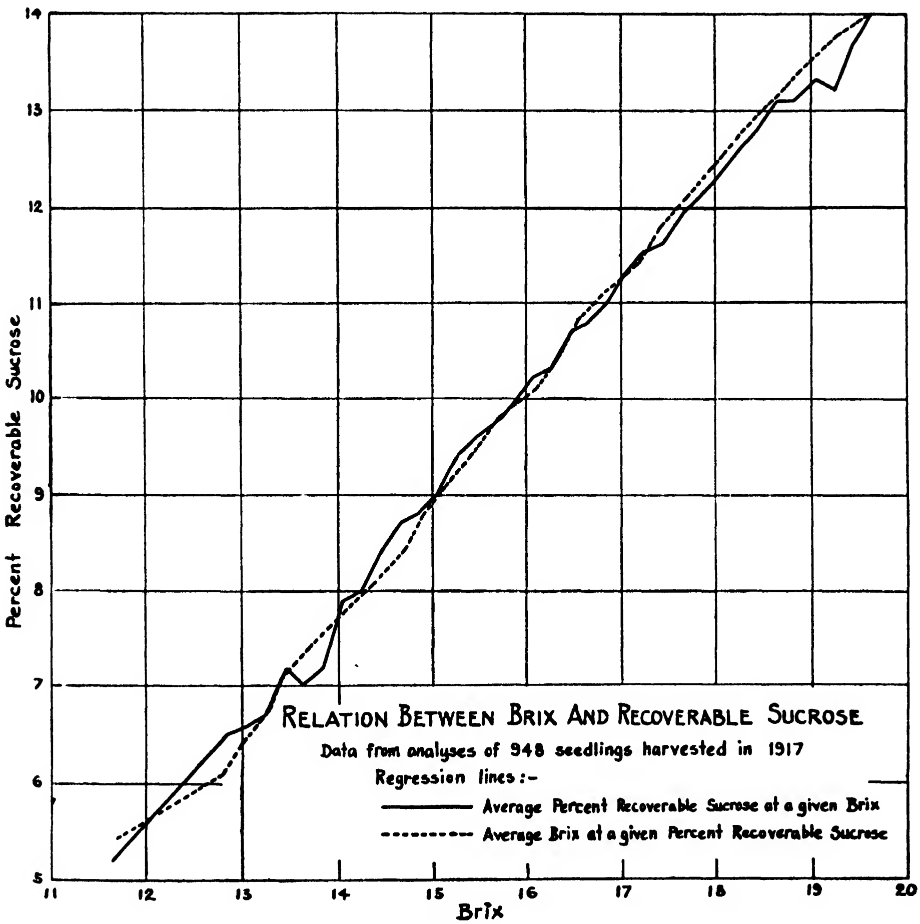


Fig. 4

Fig. 4, showing (1) the average Brix at a given per cent recoverable sucrose and (2) the average per cent recoverable sucrose at a given Brix, affords further evidence of the closeness of the correlation, since the two lines almost coincide.

The coefficients of correlation between Brix and per cent recoverable sucrose were calculated for the groups of analyses under discussion and were found to be as follows:

948 seedlings harvested in 1917	$+.967 \pm .001$
644 seedlings harvested in 1918	$+.974 \pm .008$
492 seedlings harvested in 1921	$+.925 \pm .004$
504 stools of H 109 harvested in 1927	$+.875 \pm .006$

The above figures indicate that the correlation between Brix and quality ratio is extremely close.*

As was the case with the Brix-purity relationship, the correlation was not so intense within a number of analyses of a single variety as it was between various seedlings. We cannot but believe that this is a peculiarity of the particular group of H 109 analyses under observation, rather than a general rule.

We feel more secure, since completing the calculations reported above, in using Brix as a means of estimating quality ratio under circumstances which render complete analyses impracticable. It is true that it gives only an approximation, and where a complete juice analysis is possible, the latter is of course to be preferred. However, it is reassuring to know that where Brix determinations must be resorted to, they may be relied upon to give a very good indication of juice quality.

Conclusions

1. A complete juice analysis of each seedling is not practicable where many thousands have to be examined.
2. An examination was made of the analyses of about 2000 seedlings to determine whether under such circumstances Brix is a safe basis on which to estimate juice quality.
3. A very close positive correlation was found to exist between Brix and purity; the higher the Brix, the higher the purity.
4. This relationship between Brix and purity, together with the fact that the major component of Brix is sucrose, results in an extremely close positive correlation between Brix and quality ratio.
5. It is concluded that in cases where a complete juice analysis is not feasible, a Brix or refractometer reading affords a fairly reliable basis on which to estimate juice quality.

Nitrification as a Measure of Soil Fertility

By W. T. McGeorge

During the past fifteen years fertilizer programmes on our island plantations have undergone rather extensive modification and there is no question but that a more intelligent fertilizer practice is in large part a factor in our steadily increasing

*This, of course, refers to normal cane and not to cane which has gone back from drying out too much.

sugar production. In formulating these modifications in the fertilizer programme, field experiments have played a major role, as has also the chemical analysis of the soil. Useful correlations have been established for estimating the potash and phosphate requirements of our cane lands by laboratory examination. But this is not true for the nitrogen problem. With this highly important nutrient entire dependence upon field experiments has been the rule, it being generally assumed that all our soils are in need of readily available forms of nitrogen and that it is largely a problem of "trial and error." Less attention has therefore been given to correlation between cane yields and laboratory methods of estimating nitrogen availability. This does not mean that nitrogen studies on Hawaiian soils have been overlooked, for Kelley as well as Burgess devoted considerable time to the nitrogen problem and they have recorded somewhat extensive observations.

Recently there appeared in *Mededeelingen van het Proefstation voor de Java-Suikerindustrie* (No. 3, 1928) an article by Dr. O. Arrhenius on the "Nitrogen Question in the Java Sugar Industry." From this article it appears that Arrhenius has established a correlation between the nitrate-producing power of Java soils and their fertility. He has approached his problem somewhat in the same manner by which we established our correlation between potash and phosphate availability and field performance, namely, by studying soils selected because of their known response under field conditions. By determining the nitrifying power of soils taken from a large number of field tests (ammonium sulphate seems to be the most extensively used source of nitrogen in Java) he suggested the following relation: When the nitrate production of the soil is below ten parts per million all experiments give positive response and a high ammonium sulphate application is necessary. The higher the nitrifying power of the soil the less will be the amount of ammonium sulphate required to produce the maximum crop beyond which the soil no longer responds.

At the time this article appeared in print, W. P. Alexander was in the midst of an extensive study and summary of six years of nitrogen experiments at Ewa Plantation Co., comprising some seventy-four tests in twenty-nine different fields. In view of Arrhenius' observations in Java, he submitted soil samples to the Experiment Station, requesting similar data on the twenty-nine Ewa fields. The information obtained from this study is presented for its general interest.

Nitrification and Soil Fertility

The attempt to correlate crop performance with biological activities in soils is by no means new. The soil microflora, the bacteria and fungi, are plants with plant food requirements similar to the higher plants, but with probably more active foraging properties. They consume available forms of plant food, and, to a less extent, difficultly available nutrients. Indirectly or directly, they are capable of widely varying associative reactions toward the higher plants. The nodule-forming bacteria growing in symbiosis with leguminous plants are cases in point and illustrative of many more such associations found in nature. Of the beneficial soil organisms, those fixing nitrogen from the air, those changing organic forms of nitrogen into ammonia or into nitrate, those producing carbon dioxide, and more

recently the sulphofying organisms which change organic or inorganic sulphur into sulphate, are most common. For this reason attempts to correlate biological activities with soil fertility largely involve one or more of the above. The life cycle of such organisms is relatively short, and their death and decay in large numbers should make for highly available forms of the nutrients which they have absorbed for their own subsistence. On the above basis it is not unreasonable to anticipate better fertility where biological activities are at optimum. A number of investigators, both in the United States and Europe, have devoted considerable time to such problems. In Iowa, Pennsylvania and California, for example, investigations have shown a direct relation between nitrification and ammonification and crop production. In fact, Burgess, in 1918, made such a study of our plantation soils with results which led him to conclude:

1. Ammonification tests are not suitable to differentiate between the fertilities of average Hawaiian soils, although they will often show differences between very poor and very good soils.

2. Nitrification is by far the most accurate biological soil test yet perfected for predicting probable soil fertility. In fact, it is probably the best single test of any description yet developed for ascertaining the crop-producing powers of arable soils. At least this holds for Hawaiian soils. * * * In only a very few instances have the nitrification coefficients been at variance with the known fertility of the fields from whence the samples are taken. Of course there are exceptions, and it must not be inferred that nitrification tests are able to take the place of carefully conducted chemical or vegetation experiments. Active nitrification may not be the cause of high ferility, yet those conditions which tend to promote active nitrification are very evidently identical with those which tend to give us enhanced crop yields. Furthermore, although nitrification tests may be a means of differentiating between good and poor soils, they do not tell us of the causes of the differences noted, nor do they show us exactly how to improve conditions in soils of low productivity.

Probably the most extensive study of soil biology as related to fertility is that given in a recent series of papers by S. A. Waksman of the New Jersey Experiment Station. His investigations involved the relation of bacterial counts, ammonification, nitrification, carbon dioxide evolution, rate of cellulose decomposition and nitrogen fixation. His comments on nitrification are of interest:

Soil microbiological research has not yet gone far enough to justify our using any soil microbiological factor as an index of soil productivity. Nevertheless, the author feels justified in pointing out that the data submitted, together with those published previously, bring out certain correlations, which may help in time to place in our hands quantitative as well as qualitative methods for measuring the productive power of soils.

The results presented in this paper on the nitrifying power of the soil indicate that nitrification studies can yield information for the differentiation of soil fertility * * *. However, since soil fertility is affected, aside from the biological activities of the soil, also by its physical and chemical conditions, the results should not be expected to be a mathematical function of crop productivity of a given soil.

Experimental

In order to make the data as complete as possible, the nitrification tests were made a little more thorough than is usually necessary. The soil samples were

taken by the plantation and sent early next morning to the Experiment Station. The nitrate content of a soil, as well as its nitrifying power, will usually be altered by drying the soil in the air. For this reason part of the tests were made on the soils just as they came from the field—that is, no drying out. The following is an outline of the examination:

1. The nitrate content of the soil was determined on the same day the sample was received in the laboratory—within 24 hours of the time the sample was taken.
2. The fresh soil was brought to optimum moisture content and incubated at 26°—room temperature—for 28 days.
3. The fresh soil to which ammonium sulphate was added was incubated as in 2.

The soils were then dried in the air and three further sets prepared for incubation.

4. Soil—as is—brought to optimum moisture content.
5. Ammonium sulphate added and brought to optimum moisture content.
6. Dried blood was added and the soil brought to optimum moisture.

The nitrate content of the incubated soils was then determined at the end of the 28-day incubation period by the phenoldisulphonic acid method. The first would give us a knowledge of the nitrate content of the soil in the field and therefore tell us something of the nitrification under field conditions. The second would tell us of the nitrifiability of the soil nitrogen under optimum conditions—good aeration and optimum moisture. The third would tell us of the power of the soil to nitrify ammonium sulphate. Four and 5 would give the same information as 2 and 3 after the soils had been air-dried, and 6, the nitrifying power of the air-dried soil for blood. Ammonium sulphate was added at the rate of .04 gram per 100 grams of soil, and blood at the rate of .06 gram per 100 grams of soil. Moisture was added to the soils each week to replace that lost by evaporation. The data are given in Tables I to V and shown graphically in Figs. 1 to 3. Qualitative tests were also made for nitrites, and the relative content indicated in the tables in approximation by *o* for absence, *t* for very faint test, and + marks for positive, with the relative amounts shown by the number of + marks.

TABLE I

Nitrification in Fresh Soil

(Parts per mil. N in dry soil)

Soil No.	Total N	After Incubation NasNO$_3$	Before Incubation NasNO$_3$	Formed During Incubation NasNO$_3$	Per cent N Nitrified	Nitrites
1	970	14.4	5.4	9.0	.93	0
2	1260	8.3	2.8	5.5	.44	t
3	860	1.7	2.7	0	0	0
4	830	10.6	4.0	6.6	.79	t
5	1670	11.7	4.0	7.7	.46	0
6	1250	10.3	3.9	6.4	.51	0
7	1670	11.5	4.2	7.3	.44	+
8	1680	18.4	5.6	12.8	.76	+
9	1440	6.9	7.0	0	0	+
10	1590	8.5	2.7	5.8	.34	+
11	640	2.8	2.0	.8	.12	0
12	1160	7.5	2.6	4.9	.42	0
13	730	2.2	3.4	0	0	+
14	1160	23.0	13.6	9.4	.81	+
15	1230	22.2	19.8	2.4	.19	+
16	1180	14.6	7.3	7.3	.62	+
17	1410	22.9	22.4	.5	.03	+
18	1300	6.8	3.5	3.3	.25	0
19	1370	17.4	3.6	13.8	1.01	+
20	1100	7.9	4.2	5.7	.52	+
21	3500	30.0	5.1	24.9	.71	+
22	1620	16.0	4.9	11.1	.68	+
23	1700	23.0	14.0	9.0	.53	+
24	1680	9.1	2.7	6.4	.38	+
25	1800	4.6	2.0	2.6	.14	+
26	2100	7.7	2.8	4.9	.23	+
27	1800	12.2	2.7	9.5	.53	+
28	1780	20.6	3.7	16.9	.95	+
29	1840	5.5	2.7	2.8	.15	+

TABLE II

Nitrification of Ammonium Sulphate in Fresh Soil

(Parts per mil. N in dry soil)

Soil No.	N Added as $(NH_4)_2SO_4$	After Incubation N as NO_3	After Incubation N as NO_3 in Blank	Difference N as NO_3	Nitrites
1	84.8	134	14.4	120	+
2	"	114	8.3	106	+ +
3	"	112	1.7	110	+
4	"	118	10.6	107	+
5	"	112	11.7	100	+ + +
6	"	108	10.3	98	+
7	"	121	11.5	100	+
8	"	122	18.4	104	+
9	"	120	6.9	113	+ +
10	"	118	8.5	110	+
11	"	118	2.8	115	+
12	"	123	7.5	116	+
13	"	106	2.2	104	+
14	"	116	23.0	93	+ +
15	"	114	22.2	92	+
16	"	123	14.6	108	+
17	"	132	22.9	109	+
18	"	107	6.8	100	+
19	"	105	17.4	88	+
20	"	127	7.9	119	+
21	"	138	30.0	108	+
22	"	127	16.0	111	+
23	"	131	23.0	108	+
24	"	119	9.1	110	+
25	"	119	4.6	114	+
26	"	118	7.7	110	+
27	"	114	12.2	102	+
28	"	140	20.6	119	+
29	"	66	5.5	61	+ + + +

TABLE III

Nitrification in Air-Dry Soil

(Parts per mil. N in dry soil)

Soil No.	Total N	After Incubation N as NO_3	In Soil N as NO_3	Formed During Incubation N as NO_3	Per Cent Soil N Nitrified	Nitrites
1	970	27	5.4	21.6	2.2	0
2	1260	19	2.8	16.2	1.3	+
3	860	13	2.7	10.3	1.2	+
4	830	20	4.0	16.0	1.9	+
5	1670	29	4.0	25.0	1.5	+
6	1250	28	3.9	24.1	1.9	+
7	1670	23	4.2	18.8	1.1	+
8	1680	39	5.6	33.4	2.0	+
9	1440	22	7.0	15.0	1.0	t
10	1590	22	2.7	19.3	1.2	t
11	640	17	2.0	15.0	2.3	0
12	1160	22	2.6	19.4	1.7	0
13	730	16	3.4	12.6	1.7	t
14	1160	44	13.6	30.4	2.6	+
15	1230	50	19.8	30.2	2.4	+
16	1180	31	7.3	23.7	2.0	+
17	1410	53	22.4	30.6	2.2	+
18	1300	23	3.5	19.5	1.5	+
19	1370	23	3.6	19.4	1.4	+
20	1100	28	4.2	23.8	2.2	+
21	3500	51	5.1	45.9	1.3	+
22	1620	30	4.9	25.1	1.5	+
23	1700	35	14.0	21.0	1.2	+
24	1680	29	2.7	26.3	1.6	+
25	1800	32	2.0	30.0	1.7	+ +
26	2100	24	2.8	21.2	1.0	+
27	1800	29	2.7	26.3	1.4	+
28	1780	42	3.7	38.3	2.2	+
29	1840	12	2.7	9.3	.5	+

TABLE IV

NITRIFICATION OF AMMONIUM SULFATE IN AIR-DRY SOIL

(Parts per mil. N in dry soil)

Soil No.	N Added as $(NH_4)_2SO_4$	After Incubation N as NO_3	Blank N as NO_3	Difference	Nitrites
1	84.8	133	27	106	+ + + + +
2	"	123	19	104	+
3	"	81	13	68	+ + + +
4	"	93	20	73	+ +
5	"	106	29	77	+ +
6	"	108	28	80	+ +
7	"	104	23	81	+ +
8	"	125	39	86	+
9	"	112	22	90	+
10	"	105	22	83	+
11	"	114	17	97	+ + +
12	"	118	22	96	+
13	"	95	16	79	+ + +
14	"	144	44	100	+
15	"	145	50	95	+ + +
16	"	106	31	75	+ + + +
17	"	158	53	105	+
18	"	108	23	85	+ +
19	"	104	23	81	+ + +
20	"	106	28	78	+ + + +
21	"	97	51	46	+
22	"	106	30	76	+ + + +
23	"	105	35	70	+ + + +
24	"	111	29	82	+
25	"	109	32	77	+
26	"	113	24	89	+ +
27	"	112	29	83	+ +
28	"	117	42	75	+ +
29	"	81	12	69	+ +

TABLE V

Nitrification of Blood in Air-dry Soil

(Parts per million N in dry soil)

Soil No.	N Added Blood	After Incubation N as NO_3	Blank N as NO_3	Difference	Nitrites
1	84	147	27	120	+
2	"	100	19	81	+
3	"	89	13	76	+ +
4	"	91	20	71	+ +
5	"	90	29	71	+ +
6	"	96	28	68	+ + +
7	"	94	23	71	+ +
8	"	138	39	99	+ + +
9	"	105	22	83	+
10	"	95	22	73	+
11	"	133	17	116	+
12	"	127	22	105	+
13	"	82	16	66	+ +
14	"	87	44	43	+ +
15	"	81	50	31	+ +
16	"	100	31	79	+ + +
17	"	94	53	41	+
18	"	94	23	67	+
19	"	86	23	63	+ + +
20	"	86	28	58	+ + + +
21	"	122	51	71	+ +
22	"	113	30	83	+ +
23	"	103	35	68	+ +
24	"	101	29	72	+ +
25	"	85	32	53	+ + +
26	"	94	24	70	+ +
27	"	93	29	64	+ +
28	"	106	42	64	+ +
29	"	84	12	72	+ +

In Table I is given the total nitrogen present in the soil, nitrate nitrogen present after incubating the fresh soil for 28 days, from which is also subtracted the nitrate nitrogen present in the soil, giving that formed by the nitrification of the soil nitrogen. This has been calculated, too, on the basis of per cent soil nitrogen nitrified. Table III gives similar data obtained on the same soils which were air-dried before incubation. These data are shown graphically in Figs. 1 and 2.

These data show a wide variation in the nitrifying power of Ewa soils as measured by their ability to nitrify their own nitrogen. Three soils, Nos. 3, 9 and 13, showed no nitrification during the period of incubation. Nitrification was greatly enhanced by drying the soils before incubation.

In Table II is shown the nitrifying power of the soils for ammonium sulphate, using the fresh soil, and in Table IV the same after drying the soil in the air. The nitrifying power of the fresh soil for this salt of nitrogen is excellent in all cases except soil No. 29. The effect of drying the soil was to lower the rate of nitrification of ammonium sulphate. In most cases with the fresh soil, and in a lesser number of air-dried soils, the presence of ammonium sulphate appears to stimulate additional nitrification of the soil nitrogen.

In Table V is shown the nitrifying power of the soil for the nitrogen of blood. This nitrogen, like the organic nitrogen in the soil, must first be ammonified before nitrification. With few exceptions nitrification of blood is less than that of ammonium sulphate. This would indicate some variation in the ammonifying power of these soils.

In this graph the tons cane per acre per month are shown with the nitrification data, but, as in the other graphs, there does not appear to be any correlation.

Soluble Salts in the Soils

In view of the fact that there is a wide variation in the saline content of Ewa soils, the soluble salt content of all twenty-nine samples was determined, but the data are omitted since there was no correlation with nitrifying power.

Data on Soil Samples

Since biological activities are greatly influenced by soil characters and properties, Mr. Alexander very kindly supplied rather extensive data upon the fields from which the samples were taken and these are given in Table VI.

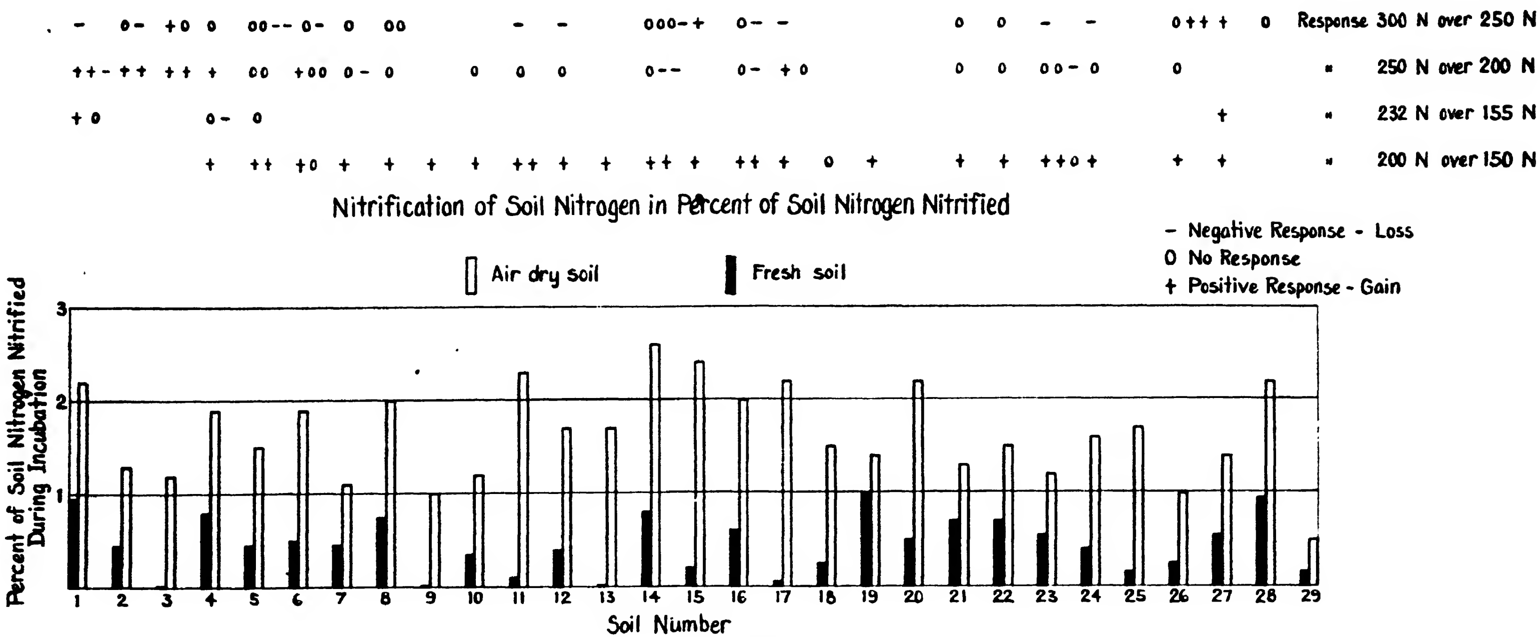

Response 300 N over 250 N
" 250 N over 200 N
" 232 N over 155 N
" 200 N over 150 N
Nitrification of Soil Nitrogen in Percent of Soil Nitrogen Nitrified
- Negative Response - Loss
0 No Response
+ Positive Response - Gain
Air dry soil
Fresh soil
Percent of Soil Nitrogen Nitrified During Incubation
Soil Number

Fig. 1

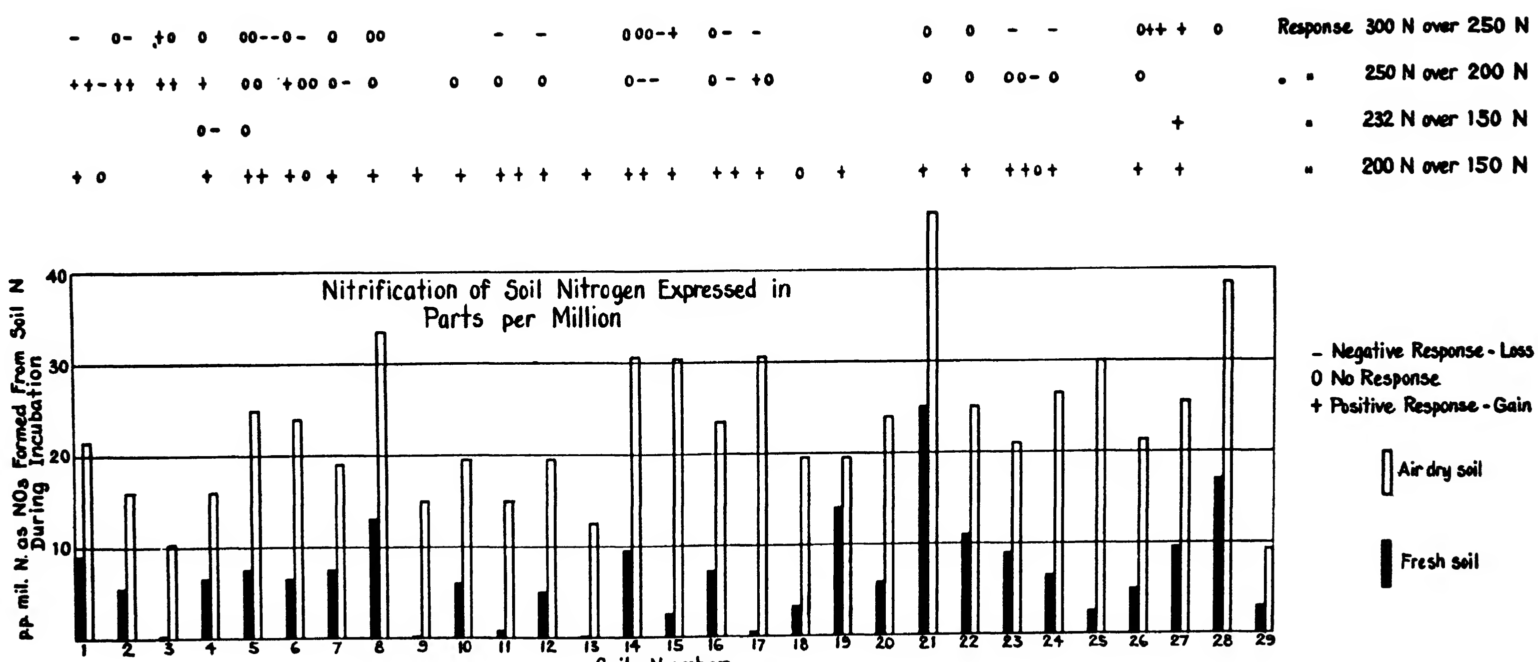

Response 300 N over 250 N
" " 250 N over 200 N
" 232 N over 150 N
" 200 N over 150 N
Nitrification of Soil Nitrogen Expressed in Parts per Million
p.p. mil. N. as NO_3 Formed From Soil N During Incubation
Soil Number
- Negative Response - Loss
0 No Response
+ Positive Response - Gain
Air dry soil
Fresh soil

Fig. 2

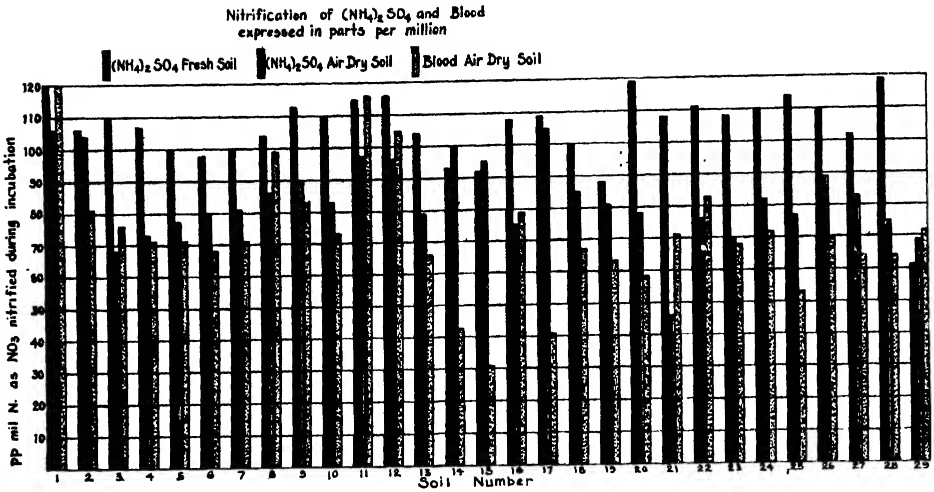

Nitrification of $(NH_4)_2SO_4$ and Blood
expressed in parts per million
$(NH_4)_2SO_4$ Fresh Soil
$(NH_4)_2SO_4$ Air Dry Soil
Blood Air Dry Soil
pp mil N. as NO_3 nitrified during incubation
Soil Number

Fig. 3

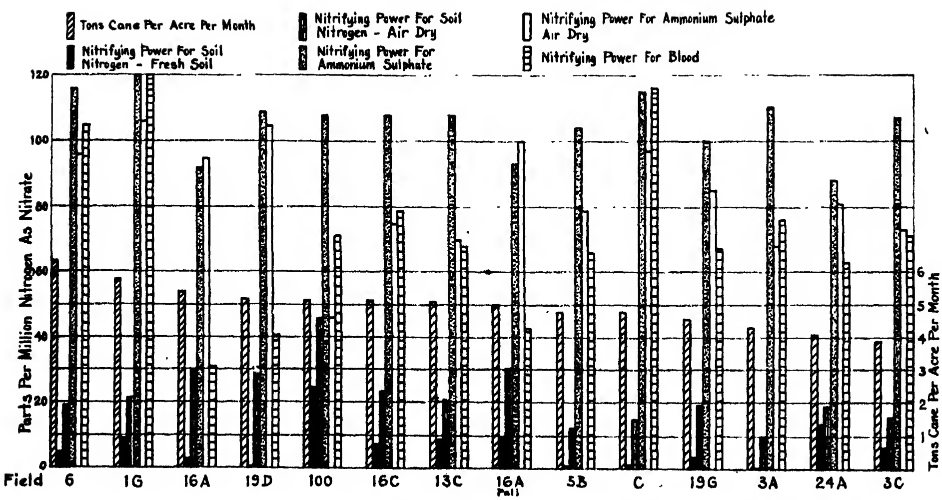

Tons Cane Per Acre Per Month
Nitrifying Power For Soil Nitrogen - Fresh Soil
Nitrifying Power For Soil Nitrogen - Air Dry
Nitrifying Power For Ammonium Sulphate
Nitrifying Power For Ammonium Sulphate Air Dry
Nitrifying Power For Blood
Parts Per Million Nitrogen As Nitrate
Tons Cane Per Acre Per Month
Field 6 1G 16A 19D 100 16C 13C 16A Fall 5B C 19G 3A 24A 3C

Fig. 4

TABLE VI

Data on Fields Where Soil Samples Were Taken from Nitrogen Experiments—May 16, 1928

First Foot Depth

Sample No.	Field	Date Sampled	Last Plowing	Last Fertilizer (75-100 lbs.)	Crop Pl. or Rat.	Age of Cane	Character of Soil*	Color of Soil
1	1G	May 14/28	1919	Mar. 31/28	1929 5th	9.0 mos.	Heavy clay	Blackish grey
2	2A	"	1921	June 15/27	1928 Sh. (3)	15.7 "	Silty clay loam	" "
3	3A	"	1926	Apr. 26/27	1930 1st	0.4 "	Heavy clay	" "
4	3C	"	1928	Apr. 5/27*	1930 Plant	1.8 "	Silty clay loam	" "
5	23A	"	1917	June 17/27	1928 Sh. (5)	15.5 "	Silty clay loam	Red
6	23B	"	1920	Feb. 14/28	1929 4th	11.1 "	Silty clay loam	Red
7	23C Mauka	"	1919	July 15/27	1928 Sh. (4)	14.9 "	Silty clay loam	Red
8	23C Makai	"	1919	"	1928 Sh. (4)	14.9 "	Silty clay loam	Red
9	Ap. 2	May 15/28	1919	July 18/27	1928 Sh. (4)	16.9 "	Silty clay loam	Red
10	B	"	1925	Feb. 7/28	1929 1st	11.8 "	Silty clay loam	Red
11	C	"	1927	Feb. 1/28	1929 Plant	9.6 "	Silty clay loam	Greyish
12	6	"	1922	Mar. 17/27	1928 2nd	25.5 "	Silty clay loam (coral)	Greyish
13	15B	"	1921	Apr. 30/27	1928 3rd	20.9 "	Silty clay loam	Greyish
14	16A Pali	"	1922	Apr. 12/28	1929 Sh. (3)	2.9 "	Silty clay loam	Red
15	16A Below	"	1920	Apr. 14/28	1929 Sh. (4)	3.0 "	Silty clay loam	Red
16	16C	"	1920	Apr. 12/28	1929 Sh. (4)	3.3 "	Heavy clay	Blackish grey
17	19D	"	1919	Feb. 3/28	1929 5th	10.0 "	Silty clay loam	Red
18	19G	"	1919	Apr. 8/27*	1929 Sh. (6)	1.2 "	Clay loam	Greyish
19	24A	"	1928	May Apr. 7/27*	1930 Plant being plowed		Silty clay loam	Red
20	26B	"	1916	June 15/27	1928 Sh. (6)	15.8 "	Clay	Black
21	10D	"	1924	Apr. 16/27	1928 1st	24.3 "	Clay loam (coral)	Red
22	13B	"	1921	Apr. 23/28	1929 Sh. (4)	2.5 "	Clay loam	Red
23	13C	"	1918	July 20/27	1928 5th	20.9 "	Silty clay loam	Red
24	14C	"	1925	Feb. 14/28	1929 1st	13.5 "	Silty clay loam	Red
25	21A	"	1923	July 14/27	1928 Sh. (2)	14.7 "	Silty clay loam	Red
26	22A Mauka	"	1918	July 1/27	1928 Sh. (5)	15.9 "	Silty clay loam	Red
27	22A Makai	"	1918	"	1928 Sh. (5)	15.9 "	Silty clay loam	Brown
28	22B	"	1923	Feb. 21/28	1929 2nd	12.7 "	Clay loam	Red
29	10B	"	1918	Aug. 8/27	1928 Sh. (6)	15.3 "	Heavy clay	Black

* Previous crop application finished.

In Fig. 5 the nitrifying power is plotted against the number of years since the fields were last plowed. It was thought that possibly the nitrifying power might be influenced by this factor, as it is characteristic of Hawaiian soils to lose in part their nitrifying power after the temporary stimulation which follows plowing (aeration). The time varies from as little as one month to twelve years, with no apparent existing relation. In Fig. 6 the nitrate content of the soil at time of sampling is plotted against the number of years since the field was last plowed, and this, too, shows little or no consistency.

In Fig. 7 an attempt is made to show graphically the relation between the time at which nitrogen was last applied to the field and the nitrate content of the soil at time of sampling. There are some data here of interest. The rapidity with which the nitrate disappears in soils 1, 16 and 22, and is retained or maintained by nitrification in 23, is of interest. The latter gives no response to nitrogen over 200 pounds, while one gave response to 250 pounds nitrogen.

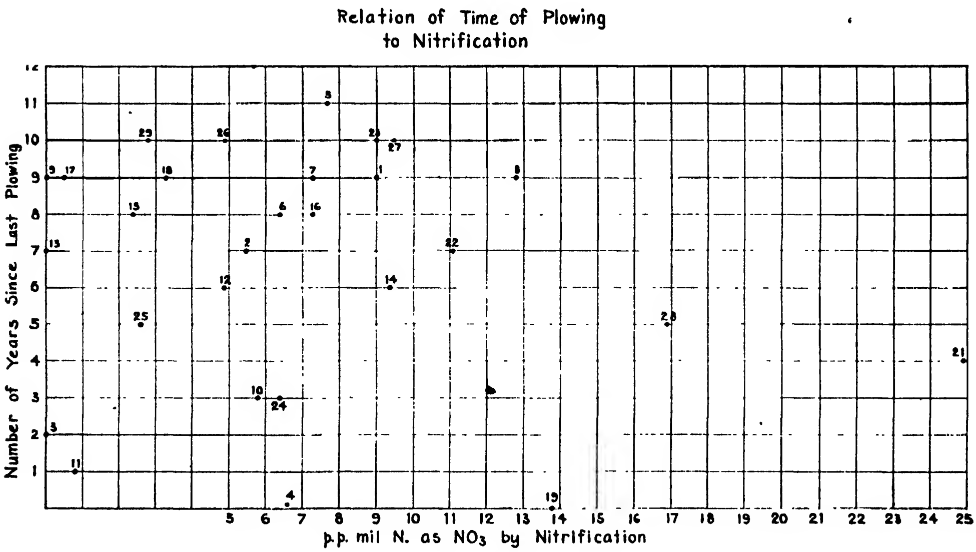


Fig. 5

Discussion

It is not possible from these data on Ewa soils to estimate to what extent Arrhenius' observations under Java conditions will apply locally. While, as already stated, Burgess, about ten years ago, conducted a similar investigation on Hawaiian soils and reached the same conclusion, his classification of fertile and unfertile is general rather than specific. That is, his investigation was not conducted upon plots from nitrogen experiments, but rather from various areas in the Islands which were classified as to cane yields, and unquestionably all Ewa fields would have fallen in his classification as fertile. It is evident from Burgess' work that he had not reached the point where any specific recommendations could be made, but had, out of a selection of nine Island soils, found that the three poorest soils—one each from poor fields at Kukuihaele, Honomu and Kipahulu—had the lowest nitrifying power when using blood as a source of nitrogen (air-dried soils).

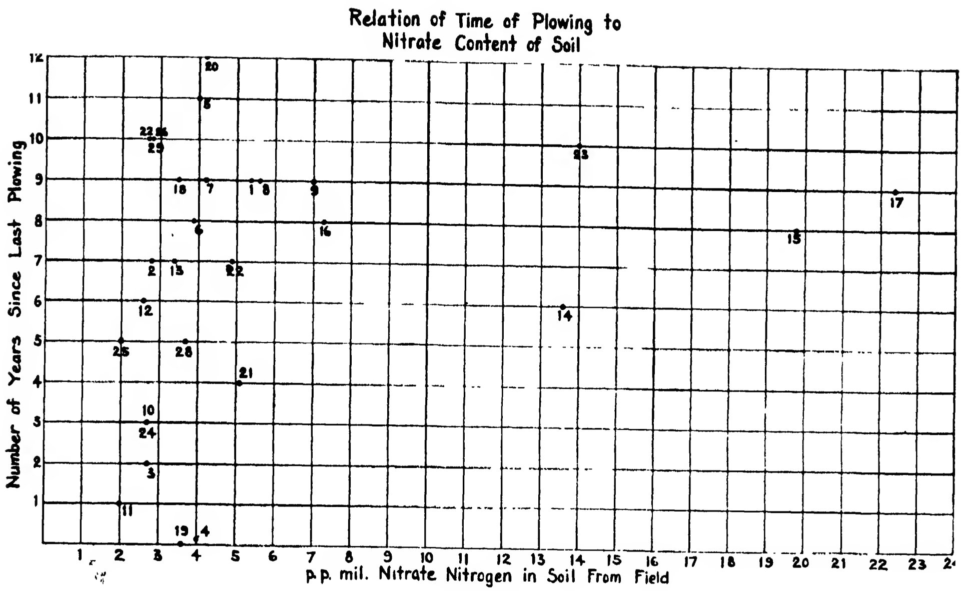

Relation of Time of Plowing to
Nitrate Content of Soil
Number of Years Since Last Plowing
p.p. mil. Nitrate Nitrogen in Soil From Field

Fig. 6

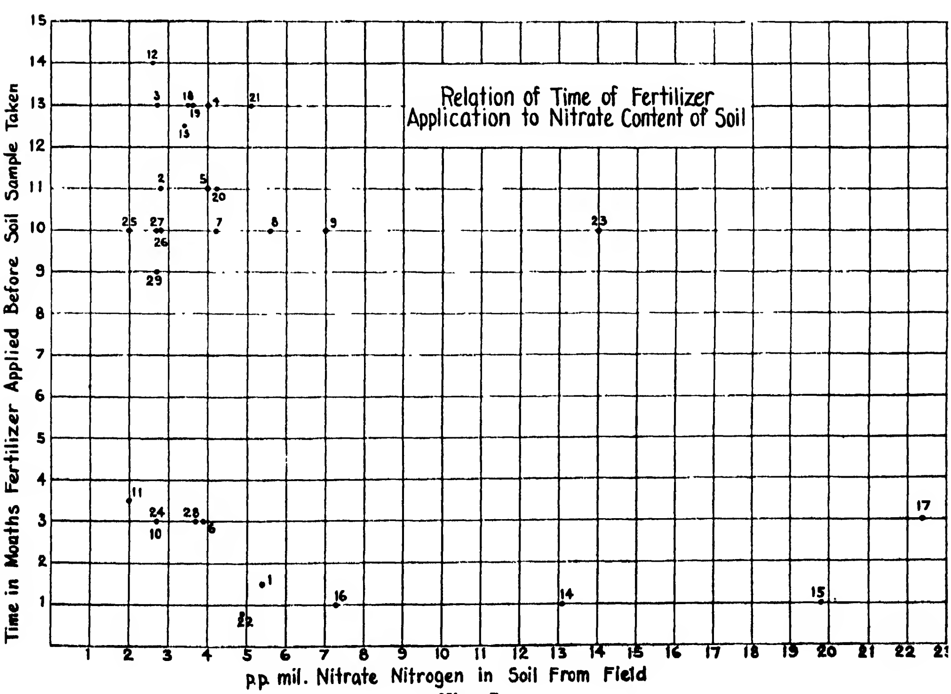

Relation of Time of Fertilizer
Application to Nitrate Content of Soil
Time in Months Fertilizer Applied Before Soil Sample Taken
p.p. mil. Nitrate Nitrogen in Soil From Field

Fig. 7

It is to be regretted that Burgess' observations were not continued to include soil studies from harvested experiments. Then, too, he did not determine the nitrifying power for the soils' own nitrogen in lieu of added ammonium sulphate and blood; nor did he include the nitrifying power of the fresh soil along with the air-dried. It is upon the power of the soil to nitrify the nitrogen naturally present that the plant must depend during the period between fertilizer applications.

Much fundamentally valuable data upon our soil nitrogen were obtained by Kelley and Burgess during their investigations. It is of interest that Burgess found nitrogen-fixing bacteria well distributed in Island soils. Out of thirty soils taken from the four largest islands, all possessed the power of fixing nitrogen from the air. From these soils he isolated four different types of nitrogen-fixing bacteria, two of which he was not able to identify. The other two were A. chroococuum and A. vinlandi.

Their work has shown, on the whole, that Hawaiian soils are well supplied with nitrogen of high solubility as measured by acids and alkali, but difficult of nitrification. To quote Kelley: "It has been shown that nitrification does not take place in Hawaiian soils unless tillage is employed, and that the effects produced by aeration may soon be destroyed by continued wet weather. Virgin soils will not support nitrification until they have undergone aeration for several months, while cultivated soils sustain active nitrification."

On a comparative basis with mainland soils, the Ewa soils have a very low nitrifying power for their own soil nitrogen. This confirms what Kelley and Burgess have already shown to be true of Hawaiian soils. In other words, the nitrogen present in our soils is of low availability. Nitrifying bacteria appear to be universally present, as is shown by the ability of our soils to nitrify ammonium sulphate and other forms of added nitrogen. Of the 29 samples of soil examined, only 4 contained nitrogen as nitrate in amounts greater than 7.3 parts per million (dry soil), which would be approximately 20 pounds nitrate nitrogen per acre foot.

In Tables I and III, the next to the last columns show the per cent of soil nitrogen nitrified during incubation, an average of .44 per cent in the fresh soil and 1.6 per cent in the air-dried soil. Compare this with data published by Burgess on soils collected from all the states in the Union, showing an average for all of 14.6 per cent (maximum 50 per cent and minimum 1 per cent). There is this difference, however, which makes the comparison more striking, that where readily nitrifiable nitrogen was added to the mainland soils there did not always follow an increased nitrification such as was obtained in all the Ewa samples. In other words, poor nitrification in these mainland soils was due in most cases to absence of nitrifying bacteria, which we have not found to be true of Island soils.

Selecting from Arrhenius' observations two of the plantations which he cites, a comparison with Ewa soils is of interest. The soils of Krebet Plantation, which is located in a fertile area, and a low user of ammonium sulphate, showed a nitrifying power—16 soil samples—of 71 to 123 parts per millon (Ewa soil 0-24 in the fresh condition and 9-45 after drying out in the air). The soils of Toelangan Plantation, which is the heaviest user of nitrogen fertilizer of all the Java plantations, showed a nitrifying power of 6-7 parts per million. On the basis, then, of

Java standards, we are forced to classify Ewa soils as requiring heavy nitrogen fertilization. The same would apply to practically all our Island soils.

Comparing the availability of nitrogen in Hawaiian and Java soils, the following is of interest: Seventeen samples of Java soils, which at time of sampling contained 1 to 21 parts per million nitrate nitrogen, increased on one month's incubation to 105 to 400 parts per million. Twenty-nine samples of Ewa soils, with nitrate nitrogen varying from 2 to 22 parts per million nitrate nitrogen at the time they were taken from the field, developed on one month's incubation 1.7—a loss—to 30 parts per million. It is evident from this that our Island soils should require much larger applications of nitrogen than Java soils.

The above comparisons indicate the difficulty to be met in making local interpretations on the basis of Java observations. On the other hand, in view of the correlations which have been noted in Java and those which Burgess had observed in our own plantation soils, such a line of investigations appears to warrant some attention as one phase of the field experiments on amounts to apply of nitrogen. In Java the heaviest application of nitrogen which is given to soils of little or no nitrifying power is 140 pounds nitrogen per acre (700 pounds ammonium sulphate). Their optimum or standard application, that which is applied to all soils, is 15 to 30 pounds nitrogen per acre. When we compare this with the minimum application of 150 pounds nitrogen it seems rather unfair to expect a correlation between nitrifying power and soil fertility in experiments in which the nitrogen is added at the rate of 150 to 300 pounds per acre. It seems fair to assume that within this range nitrogen is no longer a major growth limiting factor, and that any differences noted in yields of cane will be associated with some other condition.

Corn Root Rot Studies

The following excerpts are taken from "Corn Root Rot Studies," by B. B. Branstetter (Research Bulletin 113, University of Missouri, November, 1927). They indicate that the cause of root rot in corn is closely related to, or identical with, the cause of root rot in sugar cane:

"In 1918, when corn root rot first became recognized as a serious disease all over the corn belt, the most important manner of transmitting it was thought to be through planting seed corn infected with organisms, as *Diplodia zeae, Gibberella saubinetti, Fusarium moniliforme,* and others. . . .

"Other investigators found the organisms ordinarily present in seed corn to be responsible for seedling blights, but no direct evidence was given to show their capabilities of producing corn root rot. One type of root rot was found to occur generally when corn was grown on soils deficient in lime and available phosphate and potash. More recently, results from experiments carried on in Kentucky suggest that only seedling blight diseases result from the more common seed-borne

fungi, while true corn rot is produced by a different fungus organism that is not carried by the seed, but it is soil-borne. . . .

"Valleau has recently described corn root rot as a soil-borne disease produced by a Pythium-like organism that he was unable to isolate in pure culture. . . .

"Mention has already been made of an area in Block B of the Station field in which all the corn plants went down with badly rotted root systems in 1922. This suggested very plainly that if the corn root rot was caused by an organism it must be soil-borne in this case. Although no notes were taken on this infected area in 1921, the writer remembers with certainty that a large per cent of the plants were down in parts of the same area in 1921, when the preliminary seed treatment field experiment mentioned above was planted on this part of Block B. The spot in 1922 was located approximately in the center of the west end of Block B, a plot of ground about 130 feet square that has been handled differently from any other part of the whole field. . . .

"Previous to 1921 this plot had been seeded to sorghum in 1919 and in 1920, to corn in 1917 and 1918, and to wheat in 1916. . . .*

"The work of Hoffer and Carr, published in 1923, in which they stated that the most severe cases of root rots had been found in soils notable because of their deficiencies in lime and available phosphates, suggested to the writer to test the effects of lime and phosphate soil treatments on the appearance of corn root rot in the infected area in 1924. . . .

"The lime and phosphate were applied on the surface by hand, care being taken not to let the treatments overlap the adjoining plots. Immediately after application the material was raked in the top two or three inches of soil by hand. After a period of ten days the corn was planted by hand at the rate of two grains per hill on June 6, 1924. The soil was warm and the corn came up quickly and uniformly. From the first, the plants in the plots treated with phosphate were more vigorous, had a darker green color, and grew a little faster than the other plants. No differences were apparent in the plants of other plots.

"An observation made on July 26, just after the plants had begun to tassel, showed all plots in all parts of the field to be equally thrifty and growing well. The corn on the phosphated plots, however, still appeared more vigorous and a little larger than the remainder. Unfortunately, the writer changed his residence at this time and was not able to make further observations as the corn matured, the time at which the root rot had appeared in previous season. A member of the Experiment Station staff reported that by the first of October practically half of the plants were down in all the plots running through the infested area as mapped in 1923. No counts were made, but the report stated that there was no evidence of less root rot where the phospate or lime, or both, had been applied. This evidence, though meager, indicates that root rot is due to some soil-borne organism, or to some soil condition other than the lack of available lime or phosphate, or both, in the soil. Also, the fact that plants from diseased seed and from clean seed went down

** The cane Pythium was found by C. W. Edgerton to attack sorghum, wheat, oats and corn, producing effects similar to those on cane. In The Reference Book of the Sugar Industry of the World, July, 1928, pp. 39, 40. (H. P. A.)*

alike seemed to prove, in this case at least, that soil infection or a soil condition is a much more important factor than seed infection in producing corn root rot. . . .

"A number of greenhouse experiments were performed between growing seasons with different soils given various soil treatments. That results from greenhouse experiments can never be fully applied to field conditions was appreciated; nevertheless, it was believed that certain experiments with infected soil could be performed just as satisfactorily in the greenhouse. One great advantage of greenhouse experiments in this case was that corn plants could be grown to maturity during the period between growing seasons. Another advantage was the ability to control to a greater extent the environmental conditions under which the corn plants were grown. The object of these experiments was to secure some definite information on the organism or soil conditions causing corn root rot on the Missouri Experiment Station field. . . .

"These results quite convincingly indicated the presence in the infected soil of some causal agent producing corn root rot, and the absence of such a causal agent in the virgin or uncropped soil. . . .

"Without exception the plants grown in untreated soil had badly rotted root systems. Treatments with lime, manganese, and different amounts of sand had no deterrent effect on the development of corn root rot. Sterilization of the infected soil, however, did prevent roots growing in it from becoming diseased. This suggested that sterilization of the soil destroyed the causative agent producing root rot. And the fact that the plants growing in clean soil inoculated with *Diplodia zeae*, *Fusarium moniliforme*, and *Cephalosporium acremonium*, respectively, produced healthy root systems like those in the clean soil check plots strongly suggested that these organisms were not responsible for the diseased roots in the infected soil. . . .

"The root systems of the corn plans grown in 'clean' soil inoculated with Diplodia, Gibberella, and Fusarium showed no more root rot than the root systems of plants grown in uninoculated 'clean' soil, showing that the effect of these organisms was negligible compared with infected soil in causing corn root rot. Likewise, the unidentified species of Fusarium produced no rotting of the roots in the sterilized infected soil. But the plants growing in sterilized infected soil inoculated with 10 grams of diseased corn roots had badly rotted root systems, identical in appearance with those in infected soil. Neither of the sterilized soils inoculated with sterilized roots or planted with diseased seed produced plants showing any sign of root rot. This demonstrates the presence of the root rot organism, or agent if not an organism, in diseased corn roots; and further, that this organism or agent may be destroyed by sterilization. . . .

"The root systems of plants grown in infected soil treated with limestone, potash, and phosphate were slightly heavier and more extensively developed than the others, but they were just as badly rotted. This slight increase in growth in heavily fertilized infected soil is to be expected, inasmuch as Valleau and coworkers reported an increased root growth from fertilized infected soil compared with untreated infected soil. . . . The conclusion drawn was that the applica-

tion of neither potash, phosphate, nor limestone to the soil used reduced the amount of root rot in corn plants grown in it. . . .

"Corn root rot, as it occurs in Missouri, probably is caused by a Pythium-like organism similar to the fungus found by Carpenter to produce a root rot of sugar cane in Hawaii. The organism found by the writer in rotted corn roots is undoubtedly identical with the one Valleau and co-workers found invariably present in diseased corn roots in Kentucky. However, they were not able to isolate it in pure culture. Measurements of oospores of the organism growing in pure culture on corn roots in prune juice are the same as oospores of *Phytophthora cactorum,* and the two kinds of oospores look just alike. This suggests with practical certainty that Clinton saw oospores of this organism when he reported the occurrence of *Phytophthora cactorum* in corn stalks, the roots of which were severely infected with root rot. . . .

"From about 120 isolations from root tissue, four Pythium-like fungi were obtained in pure culture. Three of these proved to be identical, while the fourth one is apparently different only in that it produced oogonia and chlamydospores abundantly on potato dextrose agar. . . .

"Little opportunity has been afforded to study the taxonomy of the organism in order to determine definitely its identity. In a pure culture growing on corn roots in prune juice, mycelium, oogonia, and oospores are produced abundantly and chlamydospores less abundantly. The hyphae are non-septate and vary considerably in diameter, due to peculiar swellings occurring at intervals. Ordinary hyphae are 2 to 4 microns in diameter, while the swollen places vary in diameter up to 20 microns. Oogonia are spherical, averaging 30 to 32 microns in diameter. Oospores average 28 to 30 microns in diameter and almost completely fill the oogonial activity. The type of antheridium shown suggests that this organism belongs to the genus *Pythium.* No zoosporangia nor zoospores have been observed. It is practically certain, however, that the organism is not *Phytophthora cactorum,* a species of a closely related genus. . . .

"No conclusive inoculation trials have been carried out to prove the pathogenicity of the Pythium-like organism in producing typical corn root rot. Results of preliminary inoculation trials, however, are very suggestive. . . .

"From the results of investigations reported in this paper—showing that reductions in yield from planting heavily infected seed corn are due to seedling blight and not to root rot; that root rot does not develop in corn plants grown in uninfected soil inoculated with either of the four most common seed-borne organisms; that corn root rot does develop in plants grown in uninfected soil inoculated with diseased corn root containing spores and mycelium of a Pythium-like fungus; and that this Pythium-like organism may be easily re-isloated from young corn plants after being inoculated and becoming infected with a pure culture of the fungus—it is believed that corn root rot in Missouri is caused by a Pythium-like fungus similar to the one found by Carpenter to be the cause of root rot of sugar cane in Hawaii. . . .

"Corn root rot does not occur when disease-free corn seedlings are grown in virgin soil, nor in infected soil if sterilized.

"Uninfected soil inoculated with *Diplodia zeae, Gibberella saubinetti, Fusarium moniliforme,* and *Cephalosporium acremonium* produces a certain amount of seedling blight, under greenhouse conditions, but no root rot in the plants that survive. . . .

"Disease-free seedlings grown in sterilized infected soil inoculated with corn roots diseased with root rot develop into average sized plants in the greenhouse, but have badly rotted root systems typical of roots diseased with corn root rot. . . .

"A Pythium-like fungus was isolated from diseased corn roots growing in infected soil. The roots of young corn plants were successfully inoculated with this organism, which was re-isolated in pure culture from the inoculated roots. . . .

"Corn planted and inoculated with the Pythium-like organism in the field at different dates during the spring of 1927 developed typical corn root rot symptoms from the first planting, made April 16, but not from later plantings. It is suggested that the unusually low temperature of 5.6 degrees below normal during August may have been a factor in preventing development of root rot in the later corn. . . .

"Corn root rot in Missouri is probably caused by a soil-borne Pythium-like fungus."

(H. P. A.)

Notes on Pythium Root Rot

IV

By C. W. Carpenter

In the third article of this series of notes on current investigations of root rot, a working theory was outlined for further studies of the parasitic relation of *Pythium aphanidermatum* to cane roots. In the present paper is presented some experimental evidence, recently obtained, which indicates that in the theory adopted we have a field of research pertinent to the fundamental etiology of the disease.

Essentially the theory expressed was that excess or unbalanced nutrients lead to susceptibility of the roots to attack by this fungus. The nitrogenous group of nutrients was thought most likely to be in excess, or unbalanced by available potash and phosphoric acid, and was chosen for first consideration. It appeared reasonable from the history of root disease that the resistance of such varieties as H 109, Yellow Caledonia and Demerara 1135, as well as the susceptibility of the Lahaina, H 146 and E. K. 28 varieties, was associated with varietal idiosyncrasies of nutrition.

The theory of unbalanced nutrition was devised as a working hypothesis to probe the nature of some factors, the existence of which had long been suspected, and which appeared to greatly influence the course of the root disease. Since there are records of remarkable recoveries of Lahaina following unusual rainfall, and

since this variety continues to grow well in certain localities where the fungus is known to be present, we are forced to consider that the variety has not deteriorated seriously, but that the growing conditions for this particular variety in the presence of the fungus have become unsuitable over large areas. If heavy rainfall improved conditions when sufficient moisture for growth had been maintained, some soluble material might have been leached out or a suitable balance of nutrients restored. Thus, it was theoretically presumed that the root disease of Lahaina was not due to a shortage of any nutrient, but rather to an improper balance of nutrients, or the presence of some soluble material which induces susceptibility. In the light of some experiments with cane compost discussed below, it is probable that this soluble agent, if not nitrates, is at least present as a disintegration product of cane crop residues and is possibly peculiar thereto. It might accumulate in harmful amounts when the decomposition of cane trash, stubble and roots is accelerated with artificial fertilizers. Rapid disintergration occurring in the soil under our climatic conditions, with minimum moisture, simulates the process of composting with "Adco," in the compost heap.

Some thirty preliminary experiments, rather sketchy in nature, with water cultures and small soil cultures with Lahaina cane and H 109, were conducted in the past few months, to obtain an inkling of the truth or fallacy of the working theory. These experiments were not expected to demonstrate any particular fact, but were merely a preliminary probing for qualitative evidence concerning induced susceptibility. From them, considering the common tendency of isolated observations, we are justified, however, in drawing some inferences as to the general trend of the evidence. Supported by this trend, definite evidence that the working theory is essentially sound as a useful hypothesis in our studies was found in three experiments, "A," "B," and "W," cited below.

Experiments

Experiment "A."—Lahaina cane was grown in root-study boxes in thoroughly mixed soil from the Makiki fields. The root-study boxes, with glass sides, have a soil surface area of about one-third of a square foot; they are 12 inches by 4 inches by 16 inches deep, inside measurements.

Both Lahaina and E. K. 28 have grown well in the Makiki Station fields. There is no history of serious root rot of Lahaina in this location, the disease being either absent, or at least not a subject of comment. E. K. 28 grew well here, though an utter failure from *Pythium* root rot at the Alexander Street plots (cf. Experiment "B"). This Makiki field soil has but a minimum reserve of nitrogenous material, judging by the appearance of the leaves of H 109 grown therein in small cultures, the plants becoming pale green after a few weeks growth. It has the reputation of containing reserves of potash unusual for local soils.

The seed used was top cuttings of healthy Lahaina from the Mid-Pacific fields, Manoa.

After a growing period of four months and twenty-one days, no striking evidence of disease having been noted in the top growth, or in the roots visible through

the windows of the boxes, the root systems were washed out July 25th. Leaf growth had been pale except in those plants receiving applications of nitrogen.

No root rot was found either in the controls or in those to which amomnium sulphate had been applied in what was considered excessive amounts.

Fig. 1 shows the root systems of representative plants. Nos. 3 and 4 were controls and received no fertilizer. Nos. 6 and 12 received 30 cc. of 40 per cent ammonium sulphate (c.p.) in three applications of 10 cc. each, May 6th, 19th and 29th. Nos. 17 and 23 received 2 grams of sodium nitrate (c.p.) before planting, and 30 cc. of 40 per cent ammonium sulphate the same date as No. 12.

Root rot occurred in but one box of this series of twenty-four units. To this box, which had received a total of 6 grams of sodium nitrate (c.p.) without apparent effect in inducing root rot, a mulch one inch deep of well-rotted cane trash (composted with "Adco") was applied three weeks before the conclusion of the experiment. A flush of new roots about 6 inches long were all flaccid when the plant was washed out. Roots, new and white, but somewhat older, being about 10 inches long, were unaffected, as was the mass of older roots. Apparently, then, only those roots in the upper few inches of soil which were very young, or started to grow out stimulated by the leaching from the compost percolating downward, were attacked by the *Pythium* root rot. Those roots, the tips of which had passed below the zone of influence of the compost extract, entirely escaped injury, and the fungus did not attack the proximal portions of such roots, though they were in the immediate vicinity of the flaccid roots. This observation of root rot occurring in the presence of cane compost confirmed the results obtained earlier in Experiment "W", discussed below.

Experiment "B."—Seed of the same lot of Lahaina was used as in Experiment "A", twenty-four root-study boxes were filled with thoroughly mixed soil taken from the immediate vicinity of good Lahaina stools at the Alexander Street cane plot. This soil has never been fertilized with artificial fertilizers, but cropped with cane for many years. Lahaina has grown moderately well, with no definite root rot history. However, E. K. 28 failed miserably near by, in an area in which some years earlier a very large amount of cane trash had been incorporated. The E. K. 28 was fertilized twice with ammonium sulphate, but previously the area had not been fertilized, except, possibly, in very recent crops. Lahaina is growing fairly well in this area, following the poor growth of E. K. 28.

The Lahaina grew well in the root boxes, with better leaf color than in the Makiki soil (Experiment "A"). Plants receiving heavy applications of sodium nitrate were stunted, but of deeper green color than the unfertilized controls.

When washed out, July 31st, at the age of four months and fifteen days, those plants which had received an excess of sodium nitrate were badly affected with *Pythium* root rot. The typical fungus was present, even in the boxes where it had not been introduced. Apparently the fungus was naturally present, suitable conditions causing susceptibility. Moderate root rot occurred in those which had received ammonium sulphate in rather large amounts.

Since the experiment was not complete with sufficient units to furnish reliable data on amounts of nutrients harmful, or to contrast the relative effect of sodium

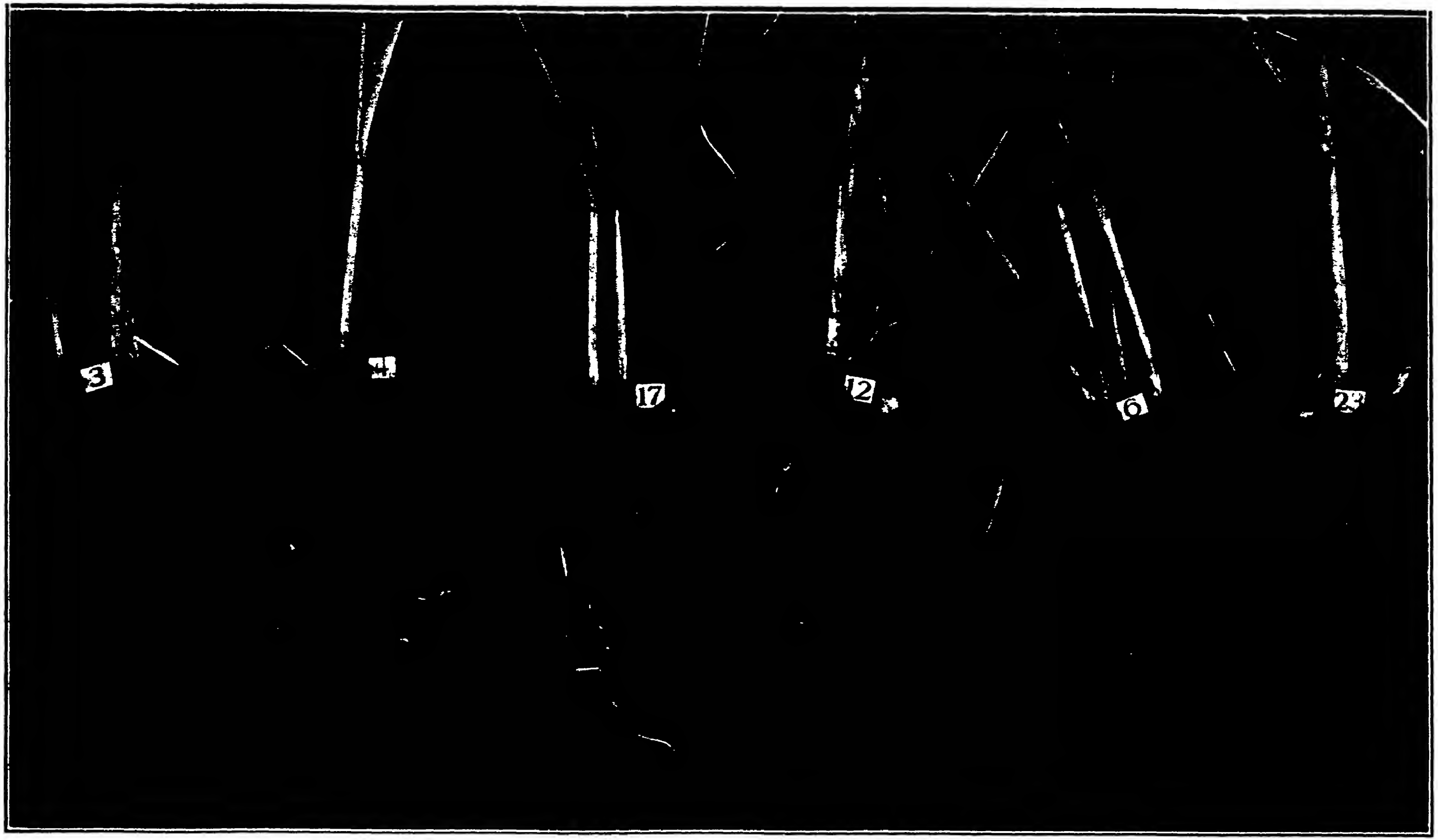


Fig. 1. Root systems of Lahaina cane in Makiki soil, with and without heavy applications of ammonium sulphate. No root rot resulted (Experiment A).

Nos. 3 and 4, controls; Nos. 6 and 12, ammonium sulphate 12 grams; Nos. 17 and 23, 2 grams sodium nitrate before planting; otherwise same treatment as Nos. 6 and 12.

Fig. 2. Root systems of Lahaina cane plants of Experiment B, with and without heavy applications of sodium nitrate. Serious root rot in Nos. 6 and 18. Nos. 4 and 7, controls; No. 5, potassium sulphate 2.0 grams; No. 6, sodium nitrate 15 grams; No. 15, ammonium sulphate 2.4 grams; No. 16, ammonium sulphate 4.8 grams and potassium sulphate 2.0 grams; No. 18, ammonium sulphate 3.2 grams and sodium nitrate 10.0 grams.

From left to right the numbers are: 4, 5, 6, 7, 15, 16, 18.

nitrate and ammonium sulphate, details of this phase are not available from our preliminary work. However, where a little ammonium sulphate was used, root rot was absent or negligible; where the amount of nitrogen added as sodium nitrate could be considered as excessive for one plant in such a limited amount of soil, root rot was serious. For example, referring to Fig. 2, the controls, Nos. 4 and 7, received no nutrients; No. 5, potassium sulphate (c.p.) 2.0 grams; No. 6 received 30 cc. of 50 per cent solution of sodium nitrate (c.p.) in three doses of 10 cc. each, on May 6th, 19th and 29th; No. 15 received 2.4 grams ammonium sulphate; No. 16, 4.8 grams ammonium sulphate, 2 grams potassium sulphate; No. 18 received 8 cc. of 40 per cent ammonium sulphate in two doses of 4 cc., on March 12th and April 3rd, and 10 grams of sodium nitrate on June 2nd. *Pythium aphanidermatum* was introduced into the soil of No. 7 on April 9th, 1928. Further tests of this type would be necessary to estimate the possible influence of excess sodium ions.

Experiment "M."—An experiment is being conducted with the variety H 109 in Waipio soil in an attempt to induce root rot with excessive applications of sodium nitrate and ammonium sulphate. It was thought that if exact conditions suitable for the development of root rot in this variety could be learned, we would have a better understanding of the sporadic cases of *Pythium* type root rot which occur, particularly in dry years, or periods of other adverse weather conditions, with this variety and others of our standard canes. Several representative boxes were washed out.

No serious root rot has yet resulted in this experiment. Some typical root rot has appeared in boxes receiving heavy applications of ammonium sulphate, followed very recently by a surface mulch of cane compost. Conversely, then, this evidence with the root-rot-resistant H 109, in connection with the rot resulting in Lahaina in some soils treated with excess nitrates, supports the general theory that varietal resistance is correlated with peculiar nutritional properties. It may be noted that in some of the first experiments (1918), H 109, D 1135 and Yellow Caledonia were grown in a potting soil rich in organic matter. It was then recorded that root rot occurred in some degree and that apparently resistance was merely a relative quality.

Fig. 3 shows: Controls Nos. 1 and 3. No. 7 received 2 cc. of a 50 per cent solution of sodium nitrate (c.p.) when planted and 25 grams of sodium nitrate fertilizer in one large dose, June 1st; No. 18 received a total of 63 cc. of 50 per cent solution of sodium nitrate in several smaller doses; No. 25 received a total of 6.5 cc. of 50 per cent sodium nitrate solution and 45 cc. of 40 per cent ammonium sulphate, besides 32 grams of calcium hydroxide (c.p.) to facilitate nitrification. Burning of leaf margins of the lower leaves and checked growth were the only marked effects of these large applications on H 109.

Construing this evidence obtained from growth of H 109 in a soil sick for Lahaina, with the fact that H 109 is susceptible to *Pythium* root rot in some degree, we have added evidence here that nitrates act indirectly rather than directly in inducing susceptibility. Experiments are now under way with H 109 in soils

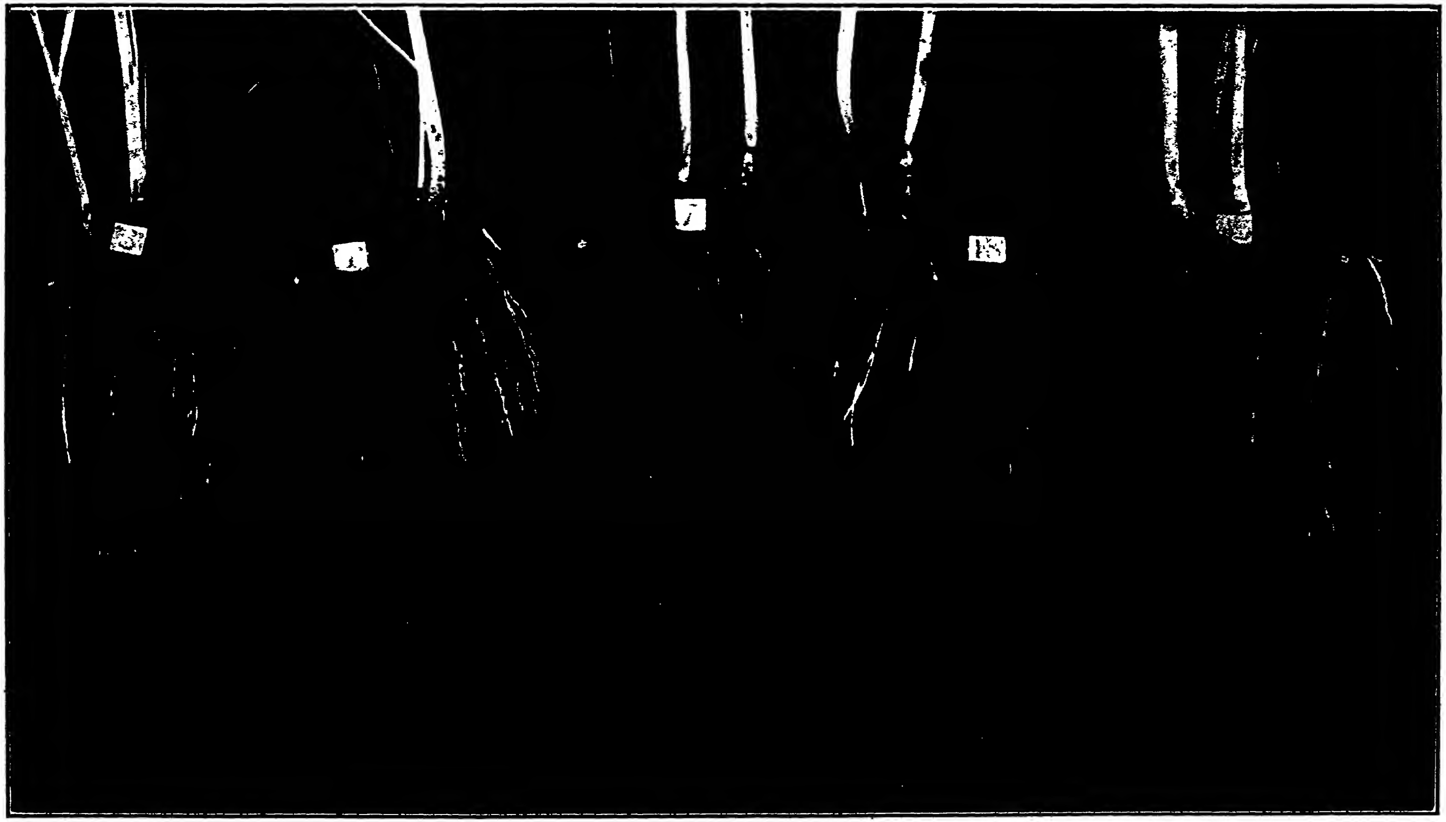


Fig. 3. Representative root system of plants of Experiment M. H 109 cane in Waipio soil.

Nos. 3 and 1, controls; No. 7, sodium nitrate 26 grams; No. 18, sodium nitrate 31.5 grams; No. 25, sodium nitrate 4.5 grams, ammonium sulphate 18.0 grams, calcium hydroxide 32.0 grams.

From left to right the numbers are: 3, 1, 7, 18, 25.

with compost amendments to which nitrates will likewise be added, in further attempts to overcome the resistance.

Experiment "W."—For a small experiment, virgin soil from an excavation in Pawaa, South King Street, was used. The control root boxes contained only virgin soil. One series contained virgin soil 75 per cent by volume and well rotted compost (cane trash composted with "Adco") 25 per cent. Another series contained virgin soil 50 per cent and compost 50 per cent. All were planted with Lahaina top cuttings from a large stool of healthy Lahaina growing at the Alexander Street field. No nutrients were added to any.

Growth was fair in the controls. Slightly longer leaves in the mixture of 25 per cent compost were noticed. The plants in the 50 per cent compost mixture were distinctly stunted, and some shoots died after a few weeks.

The roots of a few units were washed out July 5th after a growing period of three months, with the following results:

Virgin soil: The root system was normal and extensive with insignificant signs of root disease. After careful search the organism was found to be present, though not intentionally introduced, demonstrating that absence of root rot was not due to absence of the proper organism. (Figs. 4 and 5.)

Virgin soil plus 25 per cent compost: The plants appeared slightly stimulated in leaf growth compared with the controls. The root system was badly affected with *Pythium* root rot, including the young primaries from the shoot nodes. Active root rot was continuing. (Figs. 4 and 6.)

Virgin soil plus 50 per cent compost: The plants were decidedly stunted, apparently being just able to keep alive. Scarcely any roots were present. Those remaining were badly rotted and full of typical *Pythium* mycelium and oospores. This represents the final stage in root rot with complete root destruction (Fig. 4).

That less than 25 per cent of compost is effective in inducing a high degree of susceptibility in Lahaina roots is indicated by the observation noted in Experiment "A", where a surface mulch of compost brought on a bad attack. It may be noted that the agricultural department customarily uses 40 per cent of this same compost in soil for seedling propagation, so that 25 per cent compost cannot be considered an unusually extreme soil amendment. To this material the Lahaina variety appears to be very sensitive.

Fig. 4 shows the root systems of some of these plants. No. 1, control in virgin soil; No. 2, virgin soil with 25 per cent compost; No. 3, virgin soil with 50 per cent compost. Fig. 5 shows a close view of the root system of the control, and Fig. 6 of the roots in 25 per cent compost. Close inspection of the latter will reveal the rotted condition, and that the large primary roots are merely ragged remnants and empty skins.

Discussion

The preliminary results with Lahaina cane grown in mixtures of virgin soil with cane compost and in cane soil fertilized with an excess of sodium nitrate

Fig. 4. Root systems of plants of Experiment W, Lahaina cane, virgin soil with compost amendment. (No nutrients added to any.)

1. Virgin soil. 2. Virgin soil, 75 per cent, and cane compost 25 per cent by volume; serious root rot. 3. Virgin soil, 50 per cent, and cane compost 50 per cent; complete destruction of roots, and death of shoots.

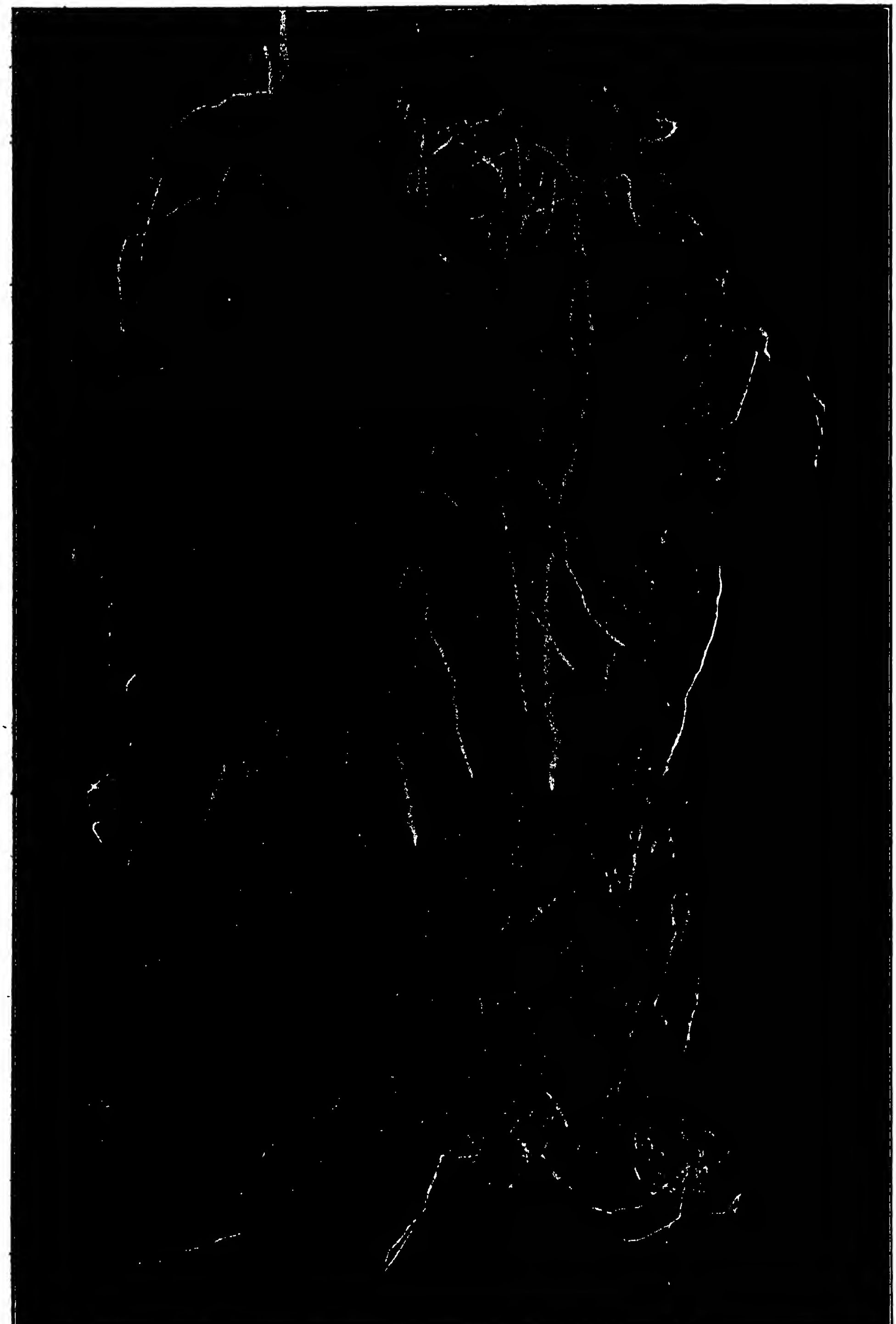


Fig. 5. Larger view of No. 1, control, shown in Fig. 4.

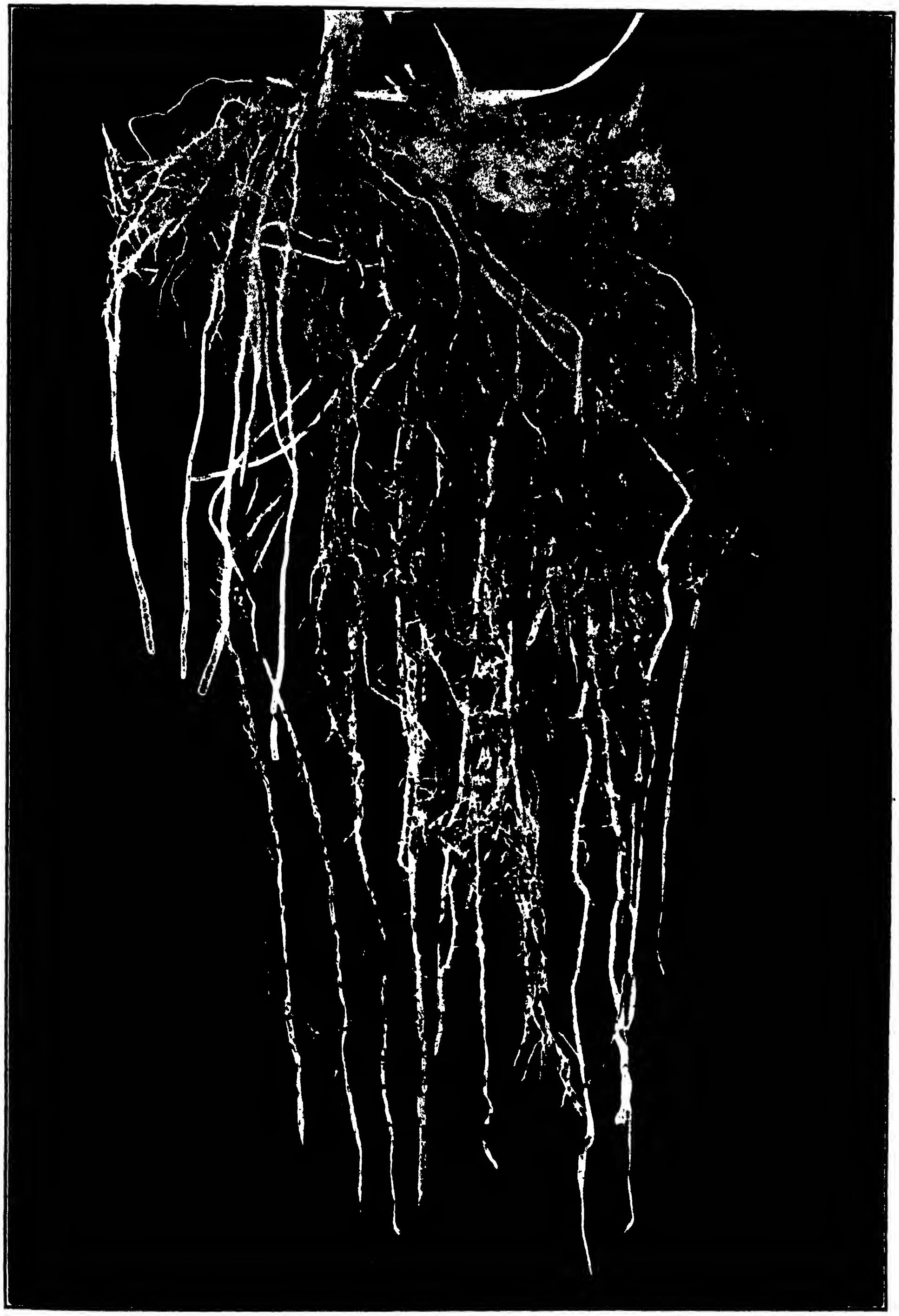


Fig. 6. Larger view of No. 2, roots in 25 per cent compost mixture with virgin soil, shown in Fig. 4. Majority of roots were flaccid, scarcely holding together for photographing.

exemplify novel features of our studies. With respect to the effect of sodium nitrate in inducing root rot in the soil from the Pathology Plot (Experiment "B") and the failure of ammonium sulphate to produce similar effect in the Makiki Station soil (Experiment "A"), our data are very meager, and few features of the two experiments are comparable. The fact that excess nitrate is in some way related to the disease is significant, and that perhaps is all that we are justified in inferring from Experiments "A" and "B". Conversely, in Experiment "M", the resistance of H 109 to the disease, maintained in a sick soil in the presence of excessive applications of ammonium sulphate and sodium nitrate, but weakening in the presence of compost leachings, appears significant from the viewpoint of varietal differences. From this experiment we obtain the hint that differences in susceptibility are correlated with nutritional or absorptive differences.

From the striking effect produced on Lahaina cane roots grown in mixtures of compost and virgin soil we are justified in inferring that the active factor in induced susceptibility is a product of the decay of cane residues (Experiment "W").

This effect of compost may be solely from the nitrogenous material it contains. That the nitrogenous fertilizers have a role in root rot we inferred from Experiments "B" and "M". It seems probable, however, that the role of inorganic nitrogenous nutrients in the soil is an indirect one, as mentioned above. Trash decomposition in the soil with minimum moisture and in the presence of fertilizers, simulates composting with "Adco." In this rapid decomposition of trash, high in cellulose, available nitrogen would be the limiting factor for the bacteria concerned. The active factor in induced susceptibility may be a product of this accelerated decay of cane trash and other organic matter facilitated by nitrates rather than a direct effect of excess nitrates or lack of nutrient balance. Unusual rainfall, which has been reported as the only unusual precedent condition to crop recoveries over large areas, would not only dilute or leach out a portion of the harmful product, but by removing soluble nitrates would check further elaboration of the substance by the bacteria.

Unless nitrates, or other inorganic nitrogenous compounds, prove to be the active factors, a consideration of possible organic nutrients appears necessary, and of that elusive quality of organic manures which profoundly affects plant growth, a quality apparently extraneous to the content of the three major nutrients. We are led, from the evidence obtained by our diffuse preliminary experimenting, to conjecture specifically on the relation of crop residues to subsequent crops of the same kind from the aspect of increased susceptibility to disease. Experiments will be continued with cane compost and other organic matter in relation to susceptibility to *Pythium* and the effect of sodium nitrate, ammonium sulphate, etc., as accelerators of trash decomposition in the soil, as well as the effect of unbalanced nutrients.

It would be interesting to know the effect of crop residues on corn root rot disease and other diseases associated with which a *Pythium*, identical with our

cane fungus or closely resembling it, has been reported.* We have some evidence that the roots of a top seed piece of Lahaina from a "healthy" soil, germinated in water, cannot be readily entered by *Pythium;* but that roots of a similar top seed piece from a plant grown in sick soil, germinated in water, are entered in a few hours. If a crop is sensitive to products of previous growth of the same crop in a soil, accelerated decomposition of such crop residues in the presence of the new crop might be expected to accentuate the harmful effects. Such acceleration of decay of residues may occur after the crop is fertilized, the various tissues of the latter, grown in the presence of the product and modified thereby, possibly becoming easy prey to more or less specific parasitic organisms.

The conditions which would be expected to foster the "composting" of cane residues in the soil—hot, dry weather and plentiful supply of nitrogen—would also tend to increase absorption as a result of increased transpiration.

Visualize the cane plant in this condition of increased susceptibility to root rot, increased absorption and transpiration, suddenly losing the major portion of the root system. We would expect to have the following effects:

(1) Positive symptoms of failure to absorb; lack of water and starvation effects: yellowing, premature drying and sloughing of lower leaves; tapering, short joints of stick, and, with susceptibility maintained, ultimate death of the stool. Few, if any roots present, and those close to the surface, since they could not, if susceptible, persist long enough to reach downward any distance.

(2) Accompanying or negative symptoms of checked growth and of failure to use nutrients or to eliminate waste products of metabolism: Abnormal accumulations in various parts of the plant of unnecessary materials, such as waste products, aluminum, iron, etc.

(3) Attack of weak parasites and saprophytes. Top rot, rind disease, red rot, etc.

Such are the chief symptoms of cane root disease as recorded by various investigators—positive symptoms of poor absorption and assimilation, and, more recently, emphasis on the negative symptoms of disturbed metabolism, accumulations, etc.

It is inferred from the evidence and hints thus far obtained in experiments on cane root diseases that we have the following effective factors in the etiology:

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* Edson, H. A. *Rheosporangium aphanidermatus*, a new genus and species of fungus parasitic on sugar beets and radishes. In Journal Agricultural Research, vol. IV, No. 4, 1915, pages 279-291. See also vol. IV, No. 2, pages 161-163.

Subramaniam, L. S. A Pythium disease of ginger, tobacco and papaya. In Mem. Department Agriculture India, vol. X, No. 4, pages 181-194, 1919.

Carpenter, C. W. Preliminary report on root rot in Hawaii, Hawaii Agricultural Experiment Station, Press Bul. No. 54, 1919. *Pythium* in relation to Lahaina Disease and Pineapple Wilt. Hawaiian Planters' Record, vol. XXIII, No. 3, 1920.

Drechsler, Charles. The cottony leak of cucumbers, caused by *Pythium aphanidermatum.* Journal Agricultural Research, vol. XXX, No. 11, 1925.

Harter, L. L., and Whitney, W. A. A transit disease of snap beans, caused by *Pythium aphanidermatum.* Journal Agricultural Research, vol. XXXIV, No. 5, pages 443-447, 1927.

Valleau, W. D., Karraker, P. E., and Johnson, E. M. Corn root rot, a soil-borne disease. Journal Agricultural Research, vol. XXXIII, No. 5, pages 453-476, 1926.

Branstetter, B. B. Corn root rot studies. University of Missouri, Agricultural Experiment Station, Res. Bul. 113, 1927.

(1) Predisposition of cane varieties in diverse degree, associated with (2) nutritional or absorptive idiosyncrasies (3) which lead to susceptibility of certain varieties to (4) *Pythium aphanidermatum.* Experiments have repeatedly demonstrated that with a susceptible variety no root rot disease results if the sick soil be sterilized, but introduction of *Pythium aphanidermatum* results in root rot. Since the fungus was harmless in virgin soil, but was destructive in virgin soil plus cane compost, the existence of factors inducing susceptibility is obvious. From other evidence in our experiments, it does not appear probable that these are physical in nature.

Summary

Evidence was obtained that susceptibility of Lahaina to root disease is acquired, and is a condition resulting from absorption of soluble substances. The latter are present in cane compost.

Sodium nitrate in excess, directly or indirectly in association with cane residues in the soil, induced susceptibility to *Pythium* root rot in Lahaina cane.

Cane compost (trash composted with "Adco") in moderate amounts in virgin soil was accompanied by a high degree of susceptibility. A mere trace of root rot was found in the virgin soil alone and the fungus was found to be present. Greater amounts of compost content resulted in total destruction of roots and death of shoots. No nitrogen or other material, except tap water, was added.

Disintegration and decomposition of cane trash, stubble and roots in the soil in hot weather, with minimum moisture, in the presence of artificial fertilizers, simulate composting with "Adco." The bacteria decomposing cellulose respond to fertilizers under proper temperature and moisture conditions. Accelerated decomposition of crop residues and organic matter in the presence of a crop might be expected to release harmful products, or tend to possible excesses of beneficial and stimulative inorganic or organic nutrients.

Under our theory of acquired susceptibility, the etiology of cane root rot in which *Pythium aphanidermatum* is the active agent, is inferred to be substantially as follows:

(1) Predisposition of cane varieties in diverse degree, associated with (2) nutritional or absorptive idiosyncrasies, such as sensitiveness to organic residues, leading in certain varieties to (3) susceptibility to (4) *Pythium aphanidermatum.*

Tests of Varying Amounts of Nitrogen and Potash in Relation to Eye Spot During the 1927-1928 Eye Spot Season

By J. P. Martin

In every test heretofore, heavy applications of nitrogen when applied late in the season have consistently increased the severity of the eye spot disease on H 109 cane, as determined by eye spot counts taken at two-week intervals during the eye spot season. These previous experiments consisted of five to seven repetitions of each treatment with plots averaging ten to twelve 35-foot lines. The tests were not harvested, thus making it impossible to determine the difference in sugar yields from the various treatments.

The experiments as presented in this article were planned by C. H. Butchart, of the Waialua Agricultural Company, Limited, H. K. Stender, of the Experiment Station, and the writer, April, 1927. The objects of these experiments were:

1. To determine by eye spot counts and growth measurements the effect of eye spot on H 109 cane receiving varying amounts of nitrogen and potash late in the season.

2. To determine the sugar yields at harvest from the plots receiving varying amounts of nitrogen and potash when applied late in the season.

It was possible to use the same experiment for eye spot as well as agricultural studies. R. E. Doty, of the Experiment Station, put the two experiments in and the writer conducted all eye spot counts and growth measurements. The areas selected for these experiments were in fields that have always been badly affected with eye spot at the Waialua Agricultural Company.

The test with varying amounts of nitrogen in relation to eye spot was located in Field Gay 1, and consisted of six repetitions of each treatment with watercourse plots averaging 0.29 of an acre each. The cane in this field was H 109 first ratoons, and the previous crop was harvested July 25-30, 1927. The nitrogen treatments to the various plots were as follows:

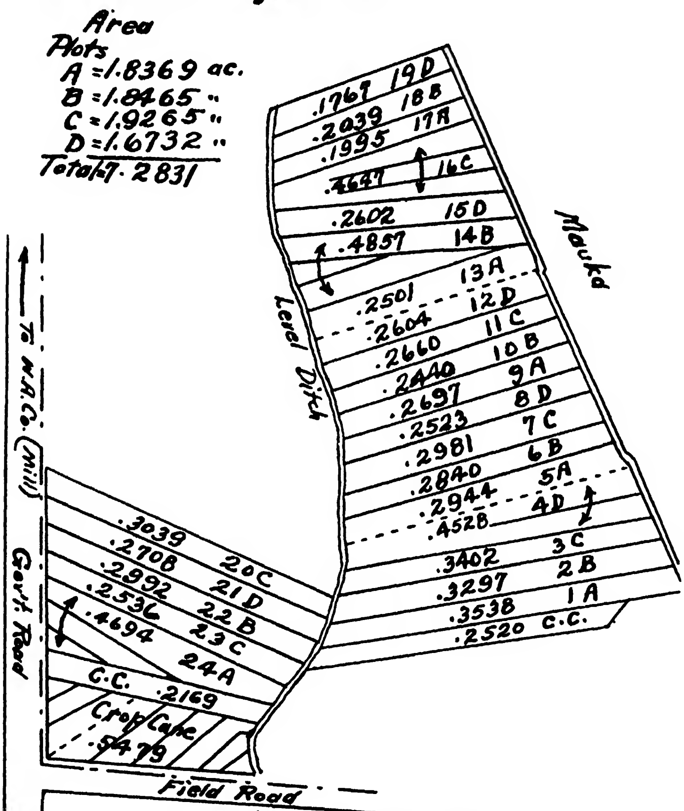
Plots	August, 1927 First Season			April, 1928 Second Season			Total		
	N	K_2O	P_2O_5	N	K_2O	P_2O_5	N	K_2O	P_2O_5
6 A............	30	35	35	100	...	...	130	35	35
6 B............	50	35	35	100	...	...	150	35	35
6 C............	70	35	35	100	...	...	170	35	35
6 D............	90	35	35	100	...	...	190	35	35

According to the soil analysis by the chemistry department, this field contained high amounts of both potash and phosphates.

Waialua Agri. Co., Exp. 18, 1929 Crop.

Field Gay 1

Fertilizer Exp. Amount of Nitrogen to apply.
Cane - H109 1st Ratoons.
Previous Crop Harvested July 25-30, 1927
24-Plots of irregular size.



Fertilization lbs. p.a.

Plots	No. of Plots	1st Season 8-27			2nd Sea.	Total		
		N	P_2O_5	K_2O	N	N	P_2O_5	K_2O
A	6	30	35	35	100	130	35	35
B	6	50	35	35	100	150	35	35
C	6	70	35	35	100	170	35	35
D	6	90	35	35	100	190	35	35

N_2 from Ammonium Sulphate
Amm. Sulphate = 20.5% N_2
Sul. of Potash = 50% K_2O
Super Phosphate = 21% P_2O_5

Fig. 1

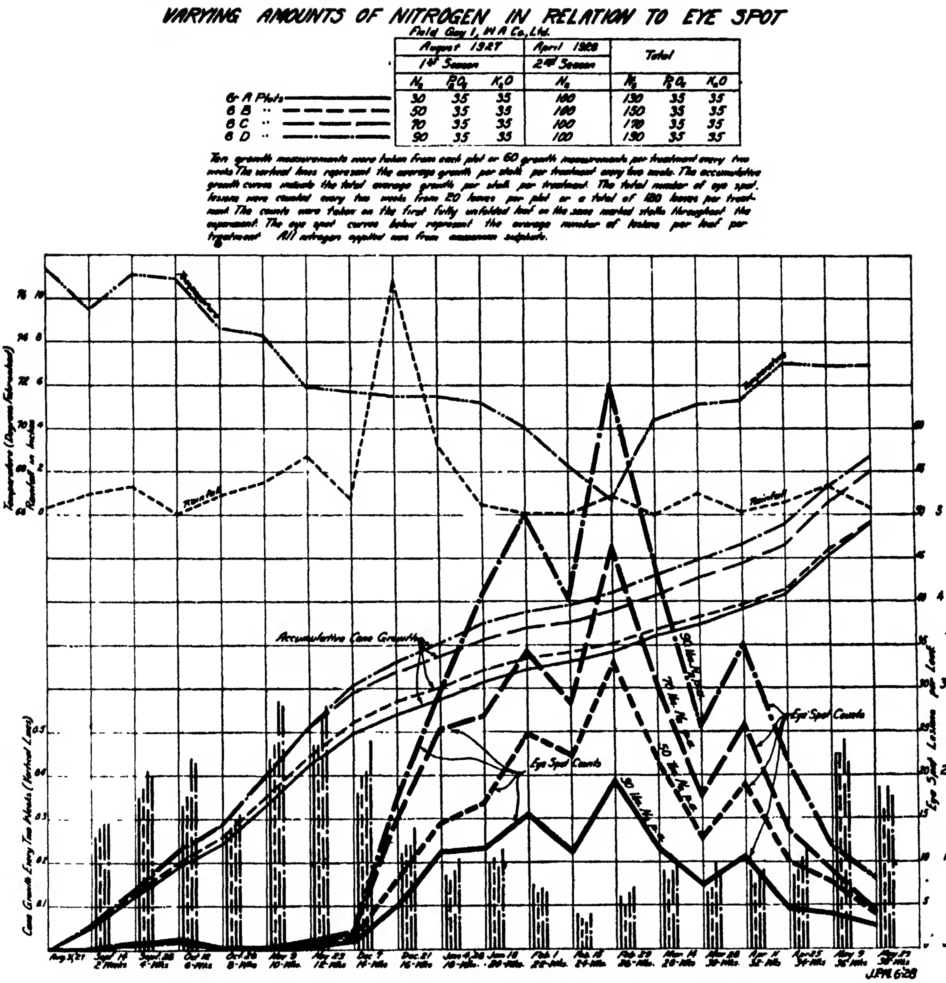


Fig. 2

All nitrogen was applied from ammonium sulphate, and a detailed plan of the experiment is given in Fig. 1. The nitrogen was applied August, 1927, during the first season, and April, 1928, during the second season.

Ten growth measurements were taken every two weeks from each plot, and the average growth per stalk per treatment is shown in Fig. 2 by the vertical lines; the accumulative cane growth is also illustrated in Fig. 2 by the curves labeled "Accumulative Cane Growth." With an increase in nitrogen there is a corresponding increase in cane growth, as brought out by the growth curves. There was only a small difference between the A and B plots, and likewise in the C and D plots. The greatest difference of cane growth occurred between the A and B plots as compared to the C and D plots. In other words, the growth response from 30 pounds of nitrogen was about the same as from 50 pounds of nitrogen per acre, and there was only .20 of a foot difference between the plots receiving 70 and 90 pounds of nitrogen per acre.

All plots received a uniform amount of nitrogen during the second season in order to determine by harvesting results the following point: Where nitrogen is reduced during the first season to control eye spot, is it necessary to make up the difference during the second season? This will be determined when the experiment is harvested in 1929.

The number of eye spot lesions on twenty leaves from each plot were counted every two weeks, and the average number of lesions per leaf per treatment is presented in Fig. 2 by the heavy curves labeled "Eye Spot Counts." It is apparent that the eye spot counts increased with the added amounts of nitrogen applied. The average number of infections or eye spot lesions per leaf from each treatment on February 29, 1928, the peak of the season, was as follows:

	Eye spot lesions per leaf February 29, 1928
A Plots—30 lbs. N per acre	19.58
B " —50 " " " "	33.37
C " —70 " " " "	46.50
D " —90 " " " "	65.11

On February 29, 1928, the D plots showed 332 per cent, the C plots 237 per cent, and the B plots 170.4 per cent more eye spot lesions per leaf than the A plots. The reduction of eye spot by decreasing the nitrogen applications to those areas subject to the disease is quite conclusive, and it will be necessary to secure the harvesting results in order to determine the sugar yield from each treatment.

Growth measurements and eye spot counts are to be taken until the experiment is harvested in 1929. Eye spot during the summer months will be negligible, but it will be interesting to learn the average number of eye spot lesions per leaf which occur throughout the summer months. A final presentation of all yields, growth measurements, and eye spot counts from each treatment will be made when the test is harvested.

At one time some were of the opinion that heavy applications of potash to fields subject to eye spot lessened the severity of the disease in a marked degree. To date, potash in all experimental work has never shown a definite control of the disease, as determined by eye spot counts. In observation tests where potash has been applied, several still maintain the disease was greatly reduced; these conclusions are merely from observations and not from quantitative measurements.

The experiment with varying amounts of potash in relation to eye spot was put in Field Mill 7, which, in the past, has been affected badly with eye spot. The field contained H 109 second ratoons and the previous crop was last harvested June 1, 1927. From the analysis by the chemistry department of the Experiment Station this particular field was low in potash. The object was to determine if a response could be secured by applying heavier applications of potash than the plantation practice, and also to study the effect of varying amounts of potash on the eye spot disease.

Six repetitions of each treatment were applied to irregular plots averaging .419 of an acre each in size. The treatments were as follows:

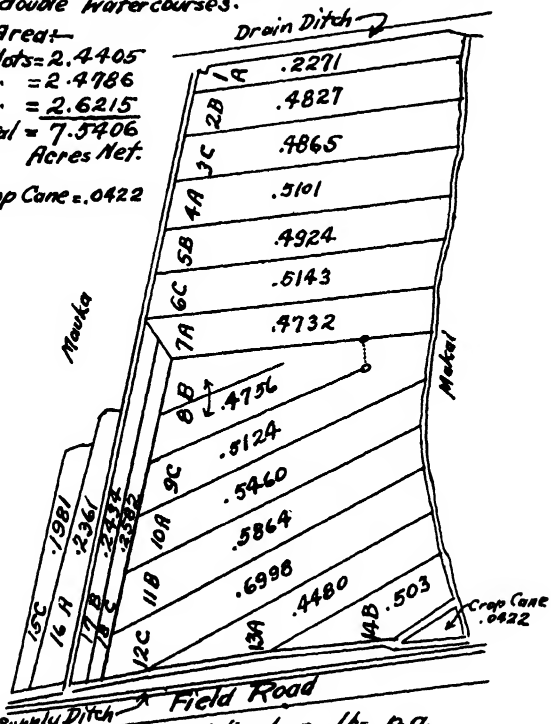
Waialua Agri. Co. Exp 8, 1929 Crop.

Field Mill 7

Fertilizer Exp.– To determine the response to varying amounts of Potash.
Cane – H109 2nd Ratoons. Previous crop harvested June 1, 1927.
18 Watercourse plots of irregular size extending from level ditch to level ditch. 2 Plots are across one level ditch. Three plots are single watercourses and 15 are double watercourses.

Areas –
A-Plots = 2.4405
B " = 2.4786
C " = 2.6215
Total = 7.5406 Acres Net.

Crop Cane = .0422



Fertilization – lbs. p.a.

Plots	No. of Plots	1st Season			2nd Sea.	Totals		
		Am. Sul. + N. S.	Sup. Phos.	Sul. Pot.	Am. Sul.	N	P_2O_5	K_2O
A	6	557	476.2	0	536.6	210	100	0
B	6	557	476.2	200	536.6	210	100	100
C	6	557	476.2	400	536.6	210	100	200

Amm. Sul. + N. S. = 18% N_2
Super Phosphate = 21% P_2O_5
Sul. of Potash = 50% K_2O
Amm. Sulphate = 20.5% N_2

Fig. 3

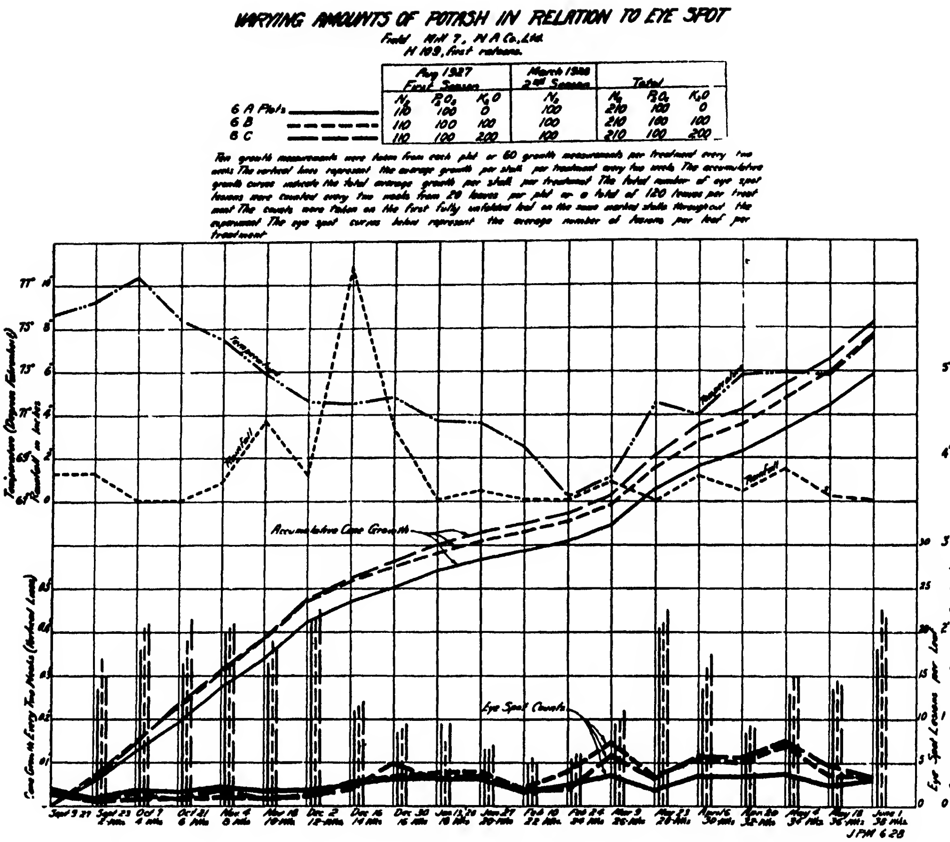


Fig. 4

	July, 1927 1st Season			April, 1928 2nd Season	Total		
	N	K_2O	P_2O_5	N	N	K_2O	P_2O_5
6 A plots..............	110	0	100	100	210	0	100
6 B "	110	100	100	100	210	100	100
6 C "	110	200	100	100	210	200	100

A detailed plan of the experiment is shown in Fig. 3.

Ten growth measurements were taken from each plot every two weeks, or a total of sixty growth measurements from each treatment at two-week intervals. The cane growth from each treatment is illustrated in Fig. 4. The plots receiving 100 and 200 pounds of K_2O showed a small gain in cane growth when compared to the plots receiving no potash, as brought out in Fig. 4 by the accumulative growth curves. The gain in cane growth from plots receiving 200 pounds of potash per acre over those receiving 100 pounds of potash per acre does not seem to warrant applying an additional 100 pounds of potash in this particular experiment. A small response in cane growth was obtained from the plots treated with potash as compared to the plots that received no potash. A greater difference may be brought out in sugar yields when the experiment is harvested during the 1929 crop.

The number of eye spot lesions on twenty leaves from each plot, or the total number of lesions from 120 leaves, were counted every two weeks from each treatment. In every case the eye spot counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The average number of infections per leaf is shown in Fig. 4 by the curves labeled "Eye Spot Counts." Very little eye spot occurred in this area during the winter months, as is shown by the eye spot curves in Fig. 4. There was not a sufficient difference in the eye spot counts to draw any conclusions regarding the various treatments of potash in relation to eye spot. Eye spot counts and growth measurements will be recorded in this experiment up to the harvesting period in 1929.

The disease during the previous season was always severe in Field Mill 7, but this past year practically no eye spot infection occurred in this field. It is necessary to put in all experiments well in advance of the eye spot season, and to know the areas subject to the disease. Even then it is possible to have such a light infection that no definite conclusions can be drawn from the various tests.

The final results of this experiment will be presented when the field is harvested.

The control of any disease depends upon the increased yields from plots receiving special treatment over those receiving no special treatment.

In Figs. 2 and 4 the rainfall and temperature for every two weeks during the experiment is plotted. A direct correlation is observed between temperature and cane growth in that with a decrease in temperature there is a decrease in cane growth and vice versa.

Fungicidal Dust Tests Against Eye Spot During the 1927 - 1928 Eye Spot Season

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By J. P. Martin

The results from the experimental research conducted with fungicidal dusts against eye spot during the 1926-1927 eye spot season were sufficiently encouraging to warrant further studies the following season. Two points were established: First, the addition of potassium permanganate as an oxidizing agent at the rate of one per cent to dusting sulphur, gave much better control of the disease when applied at weekly intervals than had been obtained before. Secondly, it was found that when calcium hydrate was used as a carrier the disease increased rapidly and the eye spot counts were greater than those from the check plots or plots receiving no dust treatment. Apparently the calcium hydrate saponified to a large extent the wax on the surface of the cane leaf, thus making it an easy matter for the fungus to penetrate the young cane leaf. It was necessary to discontinue the use of several dusts with a lime base long before the peak of the eye spot season was reached because of the sudden increase of eye spot.

With the above information it was decided to use a fine grade of dusting sulphur as the carrier for all dusts. Since sulphur plus one per cent of potassium permanganate gave such a good control of the disease, it was planned to add other oxidizing agents to sulphur, such as manganese dioxide and lead dioxide.

In fungicidal work "stickers" are often added to dusts and sprays in order that the dusts or liquid sprays may adhere better to the foliage. Upon this basis dextrin and gum tragacanth were added at the rate of one per cent to sulphur plus one per cent of potassium permanganate.

With the above knowledge the following dusts were planned by H. A. Lee and the writer to be tested during the 1927-1928 eye spot season:

Dust No.	Dust Letter	Mixture of Dust			
1	A	Sulphur			
2	B	"	plus 5%	$KMnO_4$	
3	C	"	" 1%	"	
4	D	"	" 5%	MnO_2	
5	E	"	" 5%	PbO_2	
6	F	"	" 1%	$KMnO_4$	plus 4% MnO_2
7	G	"	" 1%	"	" 1% Dextrin
8	H	"	" 1%	"	+ 1% gum tragacanth
2	I	"	" 5%	"	
3	J	"	" 1%	"	

In Field Kemoo 1 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 1. Dusts A, B, D, E and F were applied every two weeks, while Dust I was applied weekly, beginning October 28, 1927. There were six repetitions of each fungicidal dust treatment and six check plots that received no treatment. No further dust applications were applied after February 9, 1928, which was after the peak of the eye spot season.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 120 leaves were counted every two weeks from each treatment. In every case eye spot counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The average number of eye spot lesions per leaf from each treatment is shown in Fig. 2 by the heavy curves labeled eye spot counts.

The word *control* as used throughout this article signifies the difference for each treatment between the average number of lesions or infections per leaf of the treated and of the non-treated plots. The difference is secured by comparing quantitative calculations as explained in the preceding paragraph. This is not to be confused with the more practical definition of the word *control* as applied to plant diseases which compares the increase in yield of any crop due to special treatment with the yield obtained from similar plots or areas not receiving special treatment.

The object of applying fungicidal dusts to cane is to have a coating of the dust on the leaves at all times during the winter months so that the spores of the fungus upon germination are immediately killed as soon as they come in contact with the dust, thus preventing their entrance to the leaf. Once the fungus has penetrated the leaf a dust or spray that would be toxic to the development of the

organism within the leaf tissue would also be very injurious to the cane plant itself. To maintain such a coating of dust on the cane foliage during the rainy season it would be necessary to apply such dusts to the susceptible areas from two to three times a week. These numerous applications would be prohibitive on a plantation basis because of the expense that would be involved.

The damage on cane leaves resulting from eye spot is not in direct proportion to the number of infections. The seriousness of the disease depends largely on the location of the infections in the leaf itself. From each infection large runners or streaks develop, extending from the initial infection, up the vascular system, to the edge of the leaf. The tissue killed by the so-called runner is oftentimes a hundred times greater than the tissue killed by the primary infection. If ten lesions occur on a single leaf so that ten separate runners are formed, the damage is much greater than if ten lesions occur on another leaf with only five runners formed, due to the fact that certain of the infections fall within the streaks extending from lower infections on the leaf. Therefore, 50 lesions may produce the same amount of damage as 100 lesions.

Ten growth measurements were taken at two-week intervals from each plot, and the average growth per stalk per treatment is presented in Fig. 2 by the vertical lines. The accumulative cane growth from each treatment is also presented in Fig. 2 for the duration of the experiment, which was thirty-eight weeks.

The peak of the eye spot season occurred on January 19, 1928, and the per cent of control from each dust at that date was as follows:

Dust	Per Cent Control
A	31
B	44
D	45
E	41
F	43
I	46

A control with each fungicidal dust was maintained during the eye spot season, as shown in Fig. 2. On January 19, 1928, the lesions per leaf in the dusted plots varied from 128 to 161 as compared to 235 per leaf on the plots receiving no dust treatment. Field observations at this date showed that all plots were badly affected with eye spot, but a fair control was evident on the dusted plots.

The addition of "stickers," such as dextrin and gum tragacanth, did not give an added control of the disease when compared to similar dusts without the "stickers."

In Field Valley 3 of the Waialua Agricultural Company, Ltd., which contained young plant H 109 cane, the remainder of the dusts listed were tested, namely, dusts C, G, H and J, including dust A. In this experiment 42 ten-line plots were staked and labeled according to the plan as shown in Fig. 3. There were seven repetitions of each treatment, and seven check plots which received no dust applications.

Eye spot counts were taken in each plot from 20 leaves, or the total number of lesions from 140 leaves were counted every two weeks from each treatment. The

counts were taken from the first fully unfolded leaf on the same marked stalks throughout the experiment. The results of the various fungicidal dusts A, C, G, H and J, in relation to the control of the disease, are presented in Fig. 4 by the heavy curves labeled eye spot counts.

Ten growth measurements were taken at two-week intervals from each plot and the effect of each dust treatment on the cane growth is shown in Fig. 4, both by the vertical growth curves and the accumulative growth curves.

As illustrated in Fig. 4, a definite control was secured with each fungicidal dust, but no one dust showed exceptional merit. The eye spot counts started to increase rapidly about November 29, 1927, and the peak of the season was reached February 21, 1928. Two other smaller peaks occurred on April 2 and May 1, but the effects of these were negligible. The control from each dust at the peak of the eye spot season, February 21, 1928, was as follows:

Dust	Per Cent Control
J	62
A	55
C	53
G	47
H	47

A decided decrease in the accumulative cane growth was evident on the check plots when compared to the accumulative cane growth from the dusted plots as brought out in Fig. 4. The cane growth on the dusted plots at all times was practically the same. At the end of the experiment, May, 1928, a difference of one foot of cane growth was observed between the dusted plots and non-dusted plots. This difference was due to the high mortality of individual stalks resulting from top rot in the non-dusted plots.

There appears to have been a very good control from all dusts when expressd in terms of per cent. When leaves average 100 or more eye spot lesions per leaf, another 100 lesions does not add greatly to the present damage to the leaf, but there is a great difference in the control as expressed in per cent. Even though a control varying from 47 to 62 per cent was obtained with the various dusts, it would be necessary to keep the average number of lesions or infections below 60 per leaf in the experimental tests before the dust could be used on a commercial basis.

Of the dusts tested, sulphur plus one per cent of potassium permanganate, when applied at weekly intervals, gave the best control of the disease. This particular dust was also the outstanding one during the preceding eye spot season, and at that time an 89 per cent control was secured.

During the winter months frequent rains are common. In view of the experimental evidence it is necessary to apply the dusts at weekly intervals rather than at two-week intervals because a great deal of dust is washed from the foliage by the rains. It is impossible to apply the dusts at certain periods for two weeks at a time, because of daily showers or rains. Under these conditions the fungus spreads rapidly and the efficacy of any dust against eye spot applied during the winter months depends largely on the rainfall.

In Figs. 2 and 4 the rainfall and temperature are plotted every two weeks for the duration of the experiment, and a direct correlation is observed between temperature and cane growth, and also between rainfall and eye spot counts. With a decrease in temperature there is a decrease in cane growth, and with an increase in temperature there is a corresponding increase in cane growth. With an increase of rainfall there is a marked increase in the eye spot counts, and each eye spot peak, whether large or small, is accompanied by an increase in rainfall. These correlations are brought out by referring to Figs. 2 and 4.

Summary

1. Sulphur plus one per cent of potassium permanganate gave the best control of all the dusts tested. This particular dust was the outstanding dust in last year's experimental work (1926-1927).

2. The interval between two-week applications was too great during the rainy weather. Weekly applications of fungicidal dusts should be maintained during the winter months.

3. The efficacy of any dust against eye spot depends largely on the amount of rainfall and the frequency with which the dust is applied during the very wet weather.

4. Before a dust is tested out on a commercial basis, the average eye spot lesions per leaf should be kept below 60 at all times in preliminary experimental test plots.

5. There was a direct correlation between temperature and cane growth; with a decrease in temperature there was a decrease in cane growth, and with an increase in temperature there was an increase in cane growth.

6. There was also a direct correlation between rainfall and eye spot counts; with every sudden increase in eye spot counts there was a corresponding increase in rainfall slightly preceding the increase in the eye spot counts.

Sugar Prices

96° Centrifugals for the Period June 18 to Sept. 15, 1928

Date	Per Pound	Per Ton	Remarks
June 18, 1928	4.285	85.70	Porto Ricos, 4.27, 4.30.
" 19	4.32	86.40	Porto Ricos, 4.33; Philippines, 4.31.
" 22	4.30	86.00	Porto Ricos, 4.27; Cubas, 4.33.
" 26	4.3633	87.27	Porto Ricos, 4.33, 4.36; Cubas, 4.40.
" 27	4.36	87.20	Cubas.
July 3	4.33	86.60	Philippines.
" 5	4.36	87.20	Cubas.
" 6	4.345	86.90	Cubas, 4.36, 4.33.
" 10	4.255	85.10	Philippines, 4.27; Cubas, 4.24.
" 11	4.21	84.20	Cubas.
" 16	4.2025	84.05	Porto Ricos, 4.21, 415; Philippines, 4.18; Cubas, 4.27.
" 17	4.14	82.80	Cubas.
" 18	4.11	82.20	Philippines.
" 19	4.095	81.90	Philippines, 4.11; Porto Ricos, 4.08.
" 20	4.14	82.80	Cubas.
" 24	4.195	83.90	Cubas, 4.18; Porto Ricos, 4.21.
" 25	4.14	82.80	Cubas.
" 26	4.11	82.20	Cubas.
" 27	4.14	82.80	Cubas.
" 30	4.095	81.90	Cubas, 4.11, 4.08.
" 31	4.02	80.40	Cubas.
Aug. 1	4.09	81.80	Philippines.
" 2	4.11	82.20	Porto Ricos, 4.08; Cubas, 4.11, 4.14
" 3	4.065	81.30	Philippines, 4.05; Cubas, 4.08.
" 6	4.11	82.20	Cubas.
" 8	4.095	81.90	Cubas, 4.11; Philippines, 4.08.
" 9	4.11	82.20	Porto Ricos.
" 10	4.14	82.80	Cubas.
" 14	4.175	83.50	Cubas, 4.21; Philippines, 4.14.
" 15	4.24	84.80	Cubas, 4.21, 4.27; Philippines, 4.24.
" 16	4.27	85.40	Cubas.
" 20	4.14	82.80	Porto Ricos.
" 21	4.14	82.80	Cubas.
" 28	4.11	82.20	Cubas.
Sept. 10	3.975	79.50	Cubas, 3.99, 3.96.
" 11	3.96	79.20	Cubas.
" 13	3.985	79.70	Porto Ricos, 3.98; Philippines, 3.99.
" 14	3.99	79.80	Philippines.